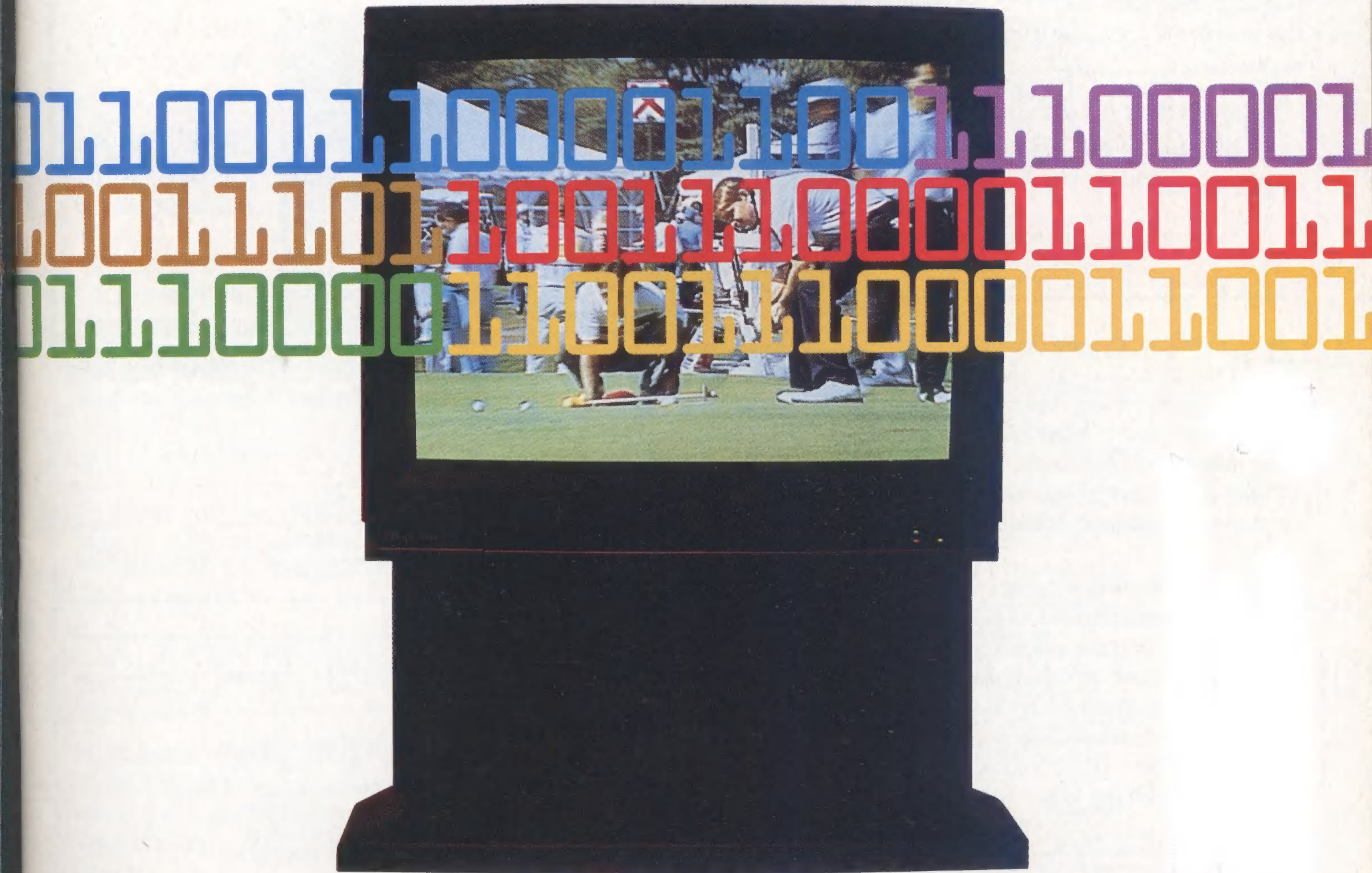
DISASTER RECOVERY P. 40

IEEE SPECTRUM

DIGITAL VIDEO



MARCH 1992 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

MATLAB™

High-Performance Numeric Computation and Data Analysis

MATLAB has rapidly become an industry standard for engineering and scientific research. Its unique interactive interface, algorithmic foundation, easy extensibility, and speed make MATLAB the software system of choice for ***high productivity and high creativity*** research.

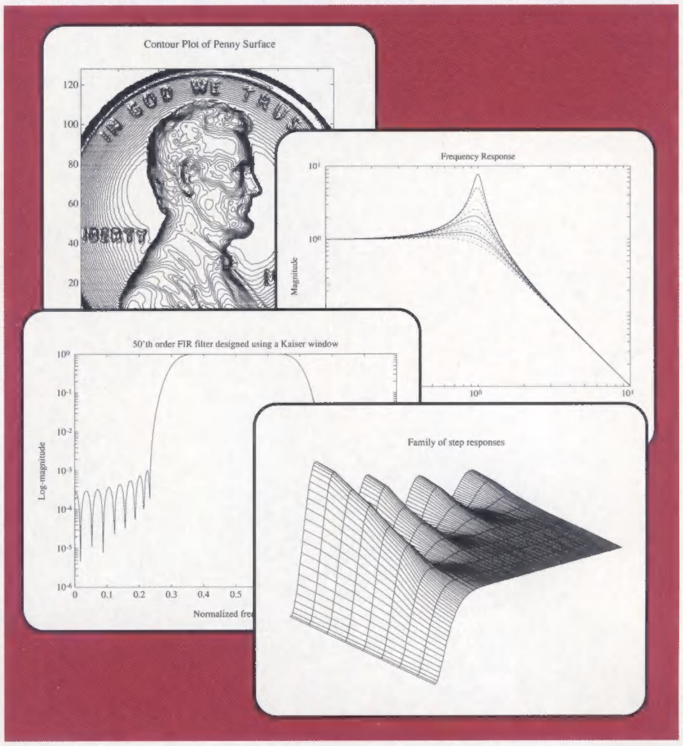
Problems and solutions are expressed just as they are written mathematically — ***without the need for traditional programming***. As a result, you can solve numerical problems in a fraction of the time required to write a program in Fortran, Basic, or C. Then plot the results as 2-D and 3-D graphics, with publication-quality output to plotters, dot-matrix printers, and laser printers.

"I can create algorithms so easily that it almost seems like cheating."

Personal Engineering & Instrumentation News

Add to MATLAB your choice of tools for digital signal processing, system identification, control system design, and more. MATLAB's open-system design lets you see the algorithms and the implementations, even change them to suit your specific requirements.

MATLAB is developed by The MathWorks, a leader in software for data analysis and mathematics. Our users — in thousands of companies and universities — know that MATLAB enables them to work more creatively and productively. Take a look at how MATLAB can do the same for you.



"MATLAB is the undisputed choice for computation-intensive engineering work."

Macworld

"MATLAB's power and ease of use go a long way toward taking the drudgery out of repetitive analysis projects."

IEEE Spectrum

Over 300 Built-In Functions

- eigenvalues
- matrix arithmetic
- matrix decompositions
- convolution
- spectrum estimation
- complex arithmetic
- 1-D and 2-D FFTs
- filtering
- curve fitting
- cubic splines
- Bessel functions
- elliptic functions
- nonlinear optimization
- linear equation solving
- differential equations
- polynomial arithmetic
- descriptive statistics
- 2-D and 3-D graphics

Plus Toolboxes for:

- digital signal processing
- parametric modelling
- control system design
- chemometric analysis, and more

Computers supported

PCs and ATs
386-based PCs
Macintosh
Sun
Apollo
HP 9000/300
DECstation
VAX/VMS
VAX/Ultrix
Stardent
Convex
Encore
Alliant
Cray
and more

To find out more about MATLAB, call us at **(508) 653-1415**. Or simply return the completed coupon to the address below.

Name ________________

Company ________________

Department ________________

Address ________________

City, State ________________

Zip ________ ***Country*** ________

Telephone ________________

Computer(s) ________________

The MATH WORKS Inc.
Cochituate Place, 24 Prime Park Way
Natick, MA 01760
Tel: (508) 653-1415
Fax (508) 653-2997

SP 3/92

Circle No. 7

Newslog

JAN 16. The **Federal Communications Commission,** Washington, D.C., said it would propose opening up 220 MHz of the radio spectrum to emerging wireless technologies like pocket cellular telephones, satellite messaging systems, and digital radio. The agency also plans to set aside a small portion of the spectrum for interactive over-the-air services enabling television viewers to shop or bank at home. The proposals drew fire from utilities and public safety agencies using those frequencies for microwave communications.

JAN 17. Micron Technology Inc., Boise, Idaho, a producer of dynamic RAMs, said it would finance the development of flat-panel display screens by **Coloray Display Corp.,** Fremont, Calif. Experts said the technology on which Coloray is working—field-emission display technology—could produce displays that are lighter, brighter, cheaper, and more energy-efficient than the active-matrix liquid-crystal displays being pursued by Japanese companies.

JAN 20. Bell Communications Research (Bellcore), Livingston, N.J., said it had established technical requirements for a switched multimegabit data service that would link long-distance, international carrier, and local telephone networks at access speeds of 1.2–34 Mb/s. The service will be offered in 30 U.S. cities by early 1993.

JAN 22. Quorum Software Systems, Menlo Park, Calif., said it had developed a program that permits users to run software designed for Apple Computer Inc.'s Macintosh PCs on Sun, IBM, and Silicon Graphics workstations. It is the first major attempt to run Macintosh software on more powerful computers using reduced-instruction-set computing (RISC) processors.

JAN 22. Sun Microsystems Inc., Mountain View, Calif., and **Cray Research Inc.,** Eagan, Minn., said that Cray would base a new line of computers in the US \$1–\$3 million range on Sun's Sparc microprocessor technology. Cray thus embraces the open system concept, which mixes hardware and software from multiple sources.

JAN 25. The Bush administration said it will not resume production of the thermonuclear weapons carried by submarine-launched Trident II missiles. The decision could shut down the Government's nuclear-bomb-building industry, which has been on hold since 1989 for environmental and safety reasons.

JAN 27. Hewlett-Packard Co., Palo Alto, Calif., and **Analog Devices Inc.,** Norwood, Mass., announced an alliance to develop mixed digital-and-analog chips. The chips will first be produced by HP with its submicrometer CMOS and BiCMOS technology, but Analog could license their manufacture at its facilities.

JAN 28. GEC Alsthom NV, Amsterdam, the Netherlands, the Anglo-French power engineering group, and **Howden Group Canada Ltd.,** Scarborough, Ont., part of the Scottish engineering company, said an international consortium to which they belong has won a \$770 million turnkey contract to build a 1100-MW power station in western Iran.

JAN 28. ABB Asea Brown Boveri Ltd., Zurich, said it had bought a 10 percent share in **Elektrim,** Warsaw, Poland, a recently privatized foreign trade company specializing in power generation, for 21 billion zloty (US \$1 million).

JAN 28. French Prime Minister Edith Cresson announced that **IBM Corp.** would buy a 5.7 percent stake in **Group Bull SA,** Paris, for \$100 million. IBM will supply Bull with its RISC technology, while Bull will make its open standards technology available to IBM.

FEB 4. ICL Ltd., the UK-based manufacturer owned by **Fujitsu Ltd.** of Japan, said the **Tartar Republic,** an autonomous republic within Russia, had agreed to finance the import of ICL computer components. ICL-Kmecs, a joint venture that ICL established last year with the republic's Kazan Manufacturing Enterprise of Computer Systems, will assemble the components in ICL's RISC machines and sell them throughout the former USSR.

FEB 5. Intel Corp., Santa Clara, Calif., and **Sharp Corp.,** Osaka, Japan, said they would develop the next generation of more powerful flash memories using 0.4- and 0.6-μm geometries. Production is to begin in Fukuyama, Japan, in 1994.

FEB 6. IBM Corp. and **National Semiconductor Corp.,** Santa Clara, Calif., announced a partnership that will focus on developing local-area network (LAN) products that make networking easier. The new relationship brings together the strongest proponents of rival LAN technologies: IBM of Token-Ring and National Semiconductor of Ethernet.

FEB 6. The Bush administration said it supported a 96-to-0 **U.S. Senate** vote on an energy bill amendment to phase out faster the production of chlorofluorocarbons (CFCs), which are damaging the protective ozone layer. The **Environmental Protection Agency** said the schedule to cease CFC production—now set for the year 2000—could be moved up by three to five years.

FEB 7. The Bush administration said it would propose to Russia a Western-financed clearinghouse for jobs for Russian nuclear engineers and scientists. The clearinghouse, to be set up in Russia, would pair the talents of 2000–3000 scientists with the needs of foreign employers willing to pay for commercial nuclear research.

FEB 8. NASA's Jet Propulsion Laboratory said that the **Ulysses** space probe was hurled southward by **Jupiter's** gravity out of the plane in which the planets orbit the sun to positions from which it will study the sun's poles, the first spacecraft to do so. A \$750 million joint effort by NASA and the **European Space Agency,** Ulysses was launched a year and a half ago.

FEB 10. Digital Equipment Corp., Maynard, Mass., said it would build its own PCs in Taiwan. The move is a shift from DEC's practice of selling only PCs manufactured by other companies, though those arrangements will continue.

FEB 12. Cray Research Inc., Eagan, Minn., said it would use the Alpha RISC microprocessor developed by **Digital Equipment Corp.,** Maynard, Mass., for a first-generation massively parallel computer. The 100-gigaflops-plus system will be delivered next year.

FEB 13. IBM Corp. said it would open a laboratory in Kingston, N.Y., for designing massively parallel supercomputers based on IBM's RISC System 6000 chip technology. The first machines are expected to be brought to market by early 1993.

Preview:

MAR 1. By this date, **IBM Corp.** and **Hewlett-Packard Co.,** Palo Alto, Calif., intend to announce a pact to develop and manufacture a family of low-cost optical-link cards using compact-disc laser technology and complying with the new American National Standards Institute Fiber Channel Standard.

COORDINATOR: Sally Cahur

MARCH 1992 Volume 29 Number 3

IEEE SPECTRUM

SPECTRAL LINES

23 Design, don't build?

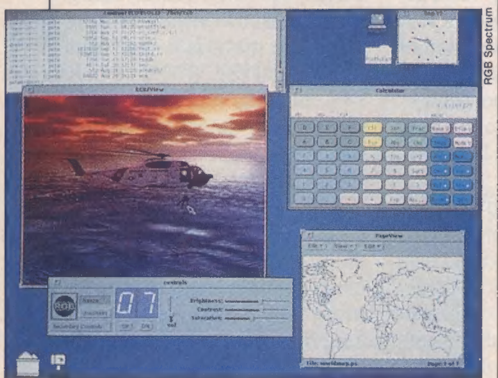
By DONALD CHRISTIANSEN

One proposal for cutting defense spending is to design, but not necessarily build, future weapons systems. Doing this could be fraught with hazards, however, unless how a system is to be built is considered in parallel with its design.

SPECIAL REPORT

24 DIGITAL VIDEO

By RONALD K. JURGEN



RGB Spectrum

The explosion in digital imaging and related technologies has already spun off the ability to combine video and computer images. For example, a computer screen (above) relying on RGB Spectrum's RGB/View 550 plug-in board, marries live TV to computer-generated text and graphics. As standards are developed, more ways to "mix and match" video, sound, and graphics are in the offing.

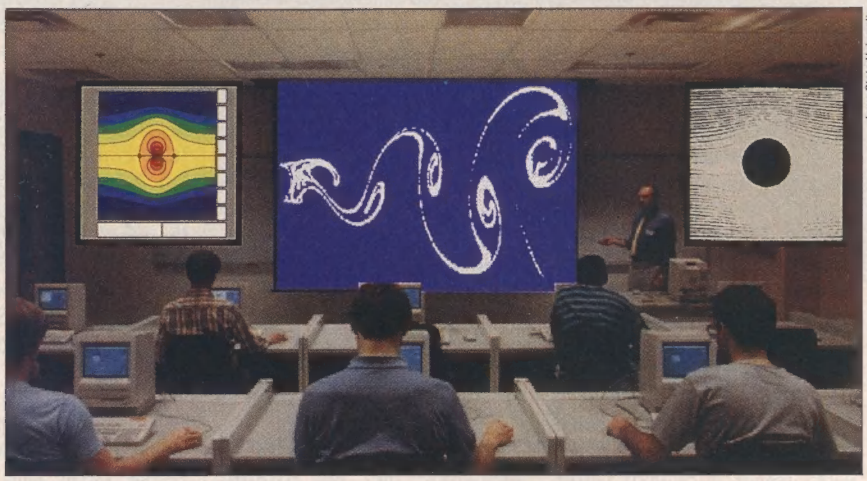
APPLICATIONS/SOLID STATE

36 Fitting logic

By THOMAS R. CLARK

Next-generation synthesis software makes life easier for logic designers by manipulating a generic logic description to yield the best possible fit for a particular field-programmable gate array or complex programmable logic device.

PERSPECTIVE/EDUCATION



Iowa State University

31 Refreshing curricula

By GEORGE F. WATSON

Engineering schools have joined to revitalize undergraduate courses so as to attract and retain students and prepare them for careers in the 21st century. The schools are weaving together design projects and multidisciplinary subjects through the four years of study, and exploiting computers, software, and advanced displays in the classroom.

BACK TO BASICS

45 After Newton, Maxwell

By PAUL J. NAHIN

Besides making sense of electromagnetic phenomena in the latter half of the 19th century, James Clerk Maxwell's famous equations achieved the second great unification in physics: they showed that the science of light and optics is a branch of electromagnetism. The astounding conclusion: electromagnetic effects travel through space at the speed of light.

SYSTEMS/COMMUNICATIONS

40 Recovery from disaster

By DENNIS BODSON and ELEANOR HARRIS

The breakup of the Bell System and the proliferation in the United States of technologies, services, and providers has challenged telecommunications systems managers during crises of national security and emergencies such as the recent San Francisco-area earthquake.

Booz-Allen & Hamilton Inc.

SIGNAL PROCESSING

46 Through a bat's ear

By JAMES A. SIMMONS, PRESTOR A. SAILLANT, and STEVEN P. DEAR

Recent experiments have shown that a bat's acoustic imaging variously combines time- and frequency-domain operations. The results encouraged the researchers to disregard conventional distinctions between these domains and to model a signal processor on the bat's acutely sensitive auditory neural system.

Steven P. Dear

COMPETITIVENESS

49 Competing in the global economy

By ROBERT M. WHITE

U.S. technology policy is wrestling with what the nation needs to compete in a global economy. Only recently has the Federal government set up an office focused purely on technology issues: the Commerce Department's Technology Administration.

51 READER SURVEY

How do you think *Spectrum* is doing? Let us know by responding to our reader survey, which asks about the articles you've read in the magazine and the articles you'd like to see us publish. And we hope you'll take the time to tell us about anything else on your mind.

3 Newslog

6 Reflections

8 Calendar

11 Books

16 Forum

18 Speakout

52 Innovations

55 Reader guide

59 EEs' tools & toys

61 Program notes

64 Scanning THE INSTITUTE

64 Coming in *Spectrum*

Cover: Digital imaging is making its mark in systems combining video and computer images. A universal header/descriptor, symbolized by artist Gus Sauter, will have an even greater impact in the future. See p. 24.

IEEE SPECTRUM (ISSN 0018-9235) is published monthly by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. © 1992 by The Institute of Electrical and Electronics Engineers, Inc., 345 East 47th St., New York, N.Y. 10017, U.S.A. Cable address: ITRIPLEE. Telex 236-411. Telecopier: 212-705-7453. *ANNUAL SUBSCRIPTIONS.* IEEE members: $10.00 included in dues. Nonmembers: $29.95. Libraries/institutions: $119. *SINGLE COPIES.* Members: $8 first copy, $16 per additional copy. Nonmembers: $16. *MICROFICHE SUBSCRIPTIONS.* Members: $16. Nonmembers and libraries: $119. *POSTMASTER:* Please send address changes to *IEEE Spectrum*, c/o Coding Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855. Second Class postage paid at New York, N.Y., and additional mailing offices. Canadian GST #125634188.

Printed at 8649 Hacks Cross Rd., Olive Branch, Miss. 38654.

IEEE Spectrum is a member of the Audit Bureau of Circulations, the Magazine Publishers of America, and the Society of National Association Publications.

Staff

EDITOR AND PUBLISHER: Donald Christiansen

EXECUTIVE EDITOR: Edward A. Torrero

MANAGING EDITOR: Alfred Rosenblatt

SENIOR TECHNICAL EDITOR: Gadi Kaplan

SENIOR EDITORS: Trudy E. Bell, Tekla S. Perry, George F. Watson

SENIOR ASSOCIATE EDITORS: John A. Adam, Glenn Zorpette

HEADQUARTERS: New York City 212-705-7555
BUREAUS: WASHINGTON, D.C., John A. Adam, 202-544-3790; *SAN FRANCISCO,* Tekla S. Perry, 415-282-3608

CORRESPONDENTS: Fred Guterl, Roger Milne (London); Bradford Smith (Paris); John Blau (Düsseldorf); Robert Ingersoll (Bonn); John Mason (Barcelona); Stuart M. Dambrot, Roger Schreffler (Tokyo); Kim Nak-Hieon (Seoul); Chris Brown (Taipei); Peter Gwynne (Hong Kong); Tony Healy (Sydney, Australia); Christopher Trump (Toronto); Axel de Tristan (Rio de Janeiro); Kevin L. Self (Houston)

CHIEF COPY EDITOR: Margaret Eastman
COPY EDITOR: Sally Cahur
EDITORIAL RESEARCHER: Alan Gardner

CONTRIBUTING EDITORS: Richard Comerford, Karl Esch, Ronald K. Jurgen, Michael J. Riezenman, Michael F. Wolff

EDITORIAL INTERNS: George Likourezos, Dana Norvila

EDITORIAL SUPPORT SERVICES: Rita Holland (Manager)
EDITORIAL ASSISTANTS: Ramona Foster, Desiree Noel

DESIGN CONSULTANT: Gus Sauter

OPERATIONS DIRECTOR: Fran Zappulla
BUSINESS MANAGER: Robert T. Ross

EDITORIAL PRODUCTION:
Carol L. White (Director)
Marcia Meyers (Manager)
Peter Ruffett (Typographer)
Morris Khan (Technical Graphic Artist)

ASSOCIATE PUBLISHER: William R. Saunders
ADMINISTRATIVE ASSISTANT: Carmen Cruz
MAIL LIST SALES: Shelly Newman (Manager), Lizette Graciani
ADVERTISING PRODUCTION:
Theresa Fitzpatrick (Manager), Francesca Silvestri

MARKETING DIRECTOR: Arthur C. Nigro
PROMOTION MANAGER: Robert D. Moran
RESEARCH MANAGER: Hendrik Prins
MARKETING SERVICES: Eric Sonntag (Administrator)

ADMINISTRATIVE ASSISTANT TO THE EDITOR AND PUBLISHER: Nancy T. Hantman

Advisory Board

Editorial Board

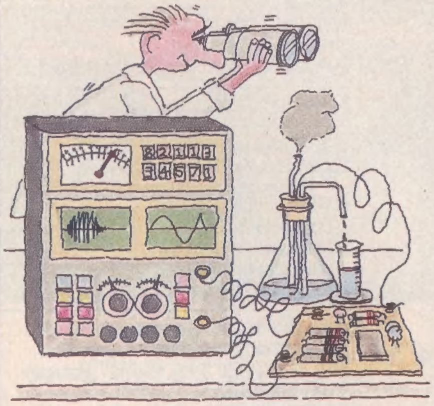
Reflections

The fashionable thing

I sat in the darkened auditorium, listening to a talk about the history of fiber optics. It was being given from the perspective of the local telephone companies—British, in this case. The projector was showing these beautiful, old, black-and-white photographs of systems experiments using a circular waveguide, the technology being pursued in the early 1960s for high-capacity transmission.

For those who may never have heard of this technique, it used a hollow pipe of about 10-cm diameter to transmit microwave signals in a mode that had extremely low attenuation—that is, as long as the pipe was absolutely straight. Well, nothing was perfect, after all.

The old slides shifted to another technology—the confocal lens. Now the pipe



carried lightwave signals, which were focused periodically by arrays of lenses. The pipe still had to be ever so straight, and there were these other problems . . .

I remembered that stuff, and the old-fashioned texture of the ancient slides made me feel like a fossil. What dumb ideas they were. How could we ever have worked on such stupid technology? It was bad enough that we struggled with that junk on our side of the Atlantic, but in Europe they were doing the same thing. So was everybody else, I guess. It was the fashion then.

It is curious how technology travels. As I go from lab to lab around the world, I see the same projects everywhere. A story starts running that NEC in Japan is working on upside-down lasers. Whispered conferences are held in Yorktown Heights, Murray Hill, Martlesham Heath, and other famous electro-metropolises.

"They say it has a fantastically high output power," says an electro-manager in a tense voice. "We have nothing like it," he adds, needlessly. The assembled researchers stare quietly at their notebooks, edging nearer to each other in order to share the collective guilt. One notebook seems to have a diagram of an upside-down laser drawn in freehand. Or perhaps the notebook itself is upside-down. In any event, later that afternoon 11 people are working on upside-down lasers.

Several weeks later at the National Science Foundation in Washington, D.C., a staff meeting is taking place. "You mean to say that we have no program in upside-down lasers?" the director is saying quietly through clenched teeth. Now the staff cringes with his sudden rise in volume. The director is shouting the ultimate threat. "What will happen to national competitiveness?!" he exclaims.

Special funds are quickly allocated at NSF. The word goes out: there is money on the street. Just say the secret words—upside-down lasers. In Cambridge, Pasadena, Palo Alto, and other electro-villages the sweet smell of available funds permeates the air. Ph.D. students confer in hallways. Upside-down lasers are fashionable. Get in while you can.

Meanwhile, in Tsukuba, Japan, there is a meeting of executives at the NEC labs. "Do we have anyone working on these—what do they call them?—upside-down lasers?" asks the chief manager. The others stir uneasily in their seats. "I regret, but, no," says the group leader. "It is an American thing," he adds with a helpless shrug. He glances sideways at the others with an expression that seems to say, "What can you do?"

Nevertheless, a team is quickly assembled, and a leapfrog project is begun. If the Americans want to push upside-down lasers, they will find the Japanese more than ready.

At the next Conference on Lasers and Electro-Optics, the sessions are filled with upside-down laser papers. Reporters for trade magazines buttonhole attendees outside the meeting rooms to get interviews for feature stories on upside-down lasers, but even those agile publications are scooped by an in-depth story in the *New York Times* science section.

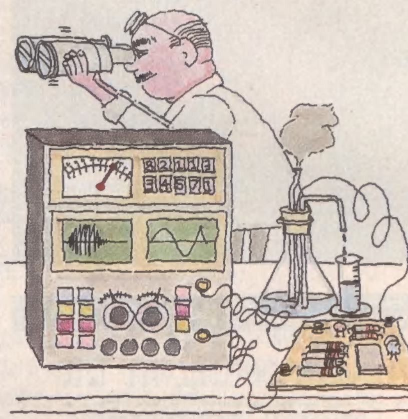
In the midst of all this clamor, a quiet rumor is being circulated in the corridors of yet another breakthrough in laser structures—this time, the sideways laser from Stuttgart. No one knows the details, but it is said that this laser has an incredibly low threshold current.

Later, back in New Jersey, the vice president looks over the long table in the executive conference room at the upturned faces of the directors. "Why are so many people working on upside-down lasers?" he asks in exasperation.

A director not responsible for laser work chimes in with the news about the German success with sideways lasers. The other directors are irked by his smug expression; they knew, too, and why bring up this old news at the staff meeting?

The director who is responsible for laser research seems to be drawing abstract doodles on his notepad. Perhaps it is a sideways laser he is drawing, but it could be that the notepad itself is sideways. Whichever, it is people as well as lasers that are about to be reoriented; fashion has changed. The story in the *New York Times*, quoting everyone about the lasting greatness of upside-down lasers, is now an embarrassment.

The history of technology is a tangled one, full of backtracking and wrong turns. Surely, that is to be expected, but the surprising thing to me is that we all seem to follow that



Gus Sauter

tortuous path together in simultaneous misadventure.

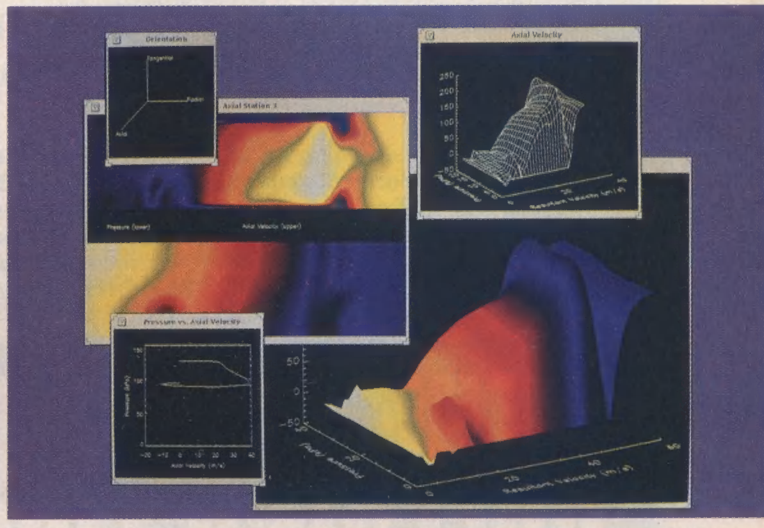
Everyone and every organization is afraid of being left out, like a child not belonging to the right clique. There is a fashion in technology, like the fashions in styles and clothes. That irresistible fashion travels across the world as an undercurrent with the speed of light.

I remember being worried years ago that my company did not have a strong position in fluidic logic or in magnetorestrictive delay lines. Not so long ago, we were scooped on cold fusion, and were running hard to keep up with high-temperature superconductivity.

Fortunately, all that is in the past. Today we are on a firm course. The *New York Times* tells me that strained quantum-well lasers are what now matters.

Robert W. Lucky

RAW. WELL DONE.



Attempting to analyze stacks of raw data can be frustrating if they can't be transformed into meaningful information that you can easily understand and use. Trends, relationships, insights, even breakthroughs, can remain buried unless you can unlock your data.

The key is PV-WAVE™ and The Visual Data Analysis Software from Precision Visuals.

PV-WAVE combines graphics with image processing, surface rendering, and animation, allowing you to visually analyze and interpret your data.

PV-WAVE™ TRANSFORMS DATA INTO DISCOVERY

"PV-WAVE gives me the power and flexibility of FORTRAN with the ease of use of my spreadsheet and a wide array of graphics capabilities."
Bill Estell
Analytical Engineer
United Technologies Hamilton Standard

With PV-WAVE, you can actually see your data, navigate through it, and display meaningful results. And, depending on your application, choose from point and click or command language versions for your Sun, DEC, HP, IBM, and SGI workstations and multi-user systems running UNIX, ULTRIX, and VMS.

If you're a scientist, engineer, researcher, or analyst who needs to turn raw data into well done results, call us today and ask about our no-risk, 60-day money-back guarantee!

Call Chris Logan today for your free video demo or evaluation copy of PV-WAVE.

1·800·447·7147

™

PV·WAVE

The Visual Data Analysis Software

Precision Visuals, Inc. 6230 Lookout Road Boulder, Colorado 80301 USA (303) 530-9000

Circle No. 32

Calendar

Meetings, Conferences and Conventions

MARCH

Eighth Annual Applied Computational Electromagnetics Society Symposium (AP); March 17–19; Naval Postgraduate School, Monterey, Calif.; Pat Foster, Microwave and Antenna Systems, 16 Peachfield Rd., Malvern, Worcs., UK WR14 4AP; (011+44) 684 574 057; fax, (011+44) 684 573 509.

Fourth International Conference on Microelectronic Test Structures (ED); March 17–19; Catamaran Resort Hotel, San Diego, Calif.; Michael W. Cresswell, National Institute of Standards and Technology, B360 Technology, Gaithersburg, Md. 20899; 301-975-2072; fax, 301-975-2128.

International Zurich Seminar on Digital Communications (Region 8); March 17–19; Swiss Federal Institute of Technology, ETH-Zentrum, Zurich; Anne Schicker, Box CH-8340 Hinwil, Switzerland; (41+1) 937 2447; fax, (41+1) 938 1557.

Multichip Module Conference (ED); March 17–20; Cocoanut Grove, Santa Cruz, Calif.; Simon Wong, Stanford University, Electrical Engineering Department, CIS 202, Stanford, Calif. 94305; 415-725-3706.

Packaging, Interconnects, Optoelectronics for the Design of Parallel Computers (LEO); March 18–19; Hyatt Regency Woodfield, Schaumburg, Ill.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331.

International Workshop on Intelligent Signal Processing and Communication Systems (C); March 19–20; International Convention Center, Taipei, Taiwan; Naohisa Ohta, NTT Transmission Systems Laboratories, 1-2356, Take Yokosuka-shi 238-03, Japan; (81) 468 59 2072; fax, (81) 468 59 3014.

International Conference on Acoustics, Speech, and Signal Processing (SP); March 23–26; San Francisco Marriott, San Francisco; Marcia A. Bush, Xerox PARC, 3333 Coyote Hill Rd., Palo Alto, Calif. 94304; 415-494-4391.

Sixth International Parallel Processing Symposium (C); March 23–26; Beverly Hilton Hotel, Beverly Hills, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 908-562-3878; submit conferences for listing to: Ramona Foster, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7305.

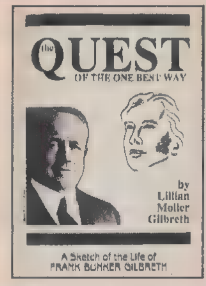
For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Books

The father of 'the dozen,' by his wife

Ronald G. Greenwood

The Quest of the One Best Way: A Sketch of the Life of Frank B. Gilbreth. *Gilbreth, Lillian Moller, Society of Women Engineers, New York, 1990, 88 pp., $20.*



Ernestine Gilbreth Carey, one of the 12 children of the famous engineering duo Frank and Lillian Gilbreth, was most thoughtful in sending me a copy of her late mother's recently republished book. I had read an older printing quite some time ago and enjoyed a rereading with equal enthusiasm. The book, only 88 pages long, is written with the most vibrant power by an author who was as much a wordsmith as she was a mother and engineer.

Simply stated, the book is about the life of one of the United States' greatest engineers, who also happened to pioneer scientific management and studies of motion. The Gilbreths are famous for their use of photographs and other techniques to study motion so as to improve the speed and lessen the fatigue of doing work; out of these studies sprang the fields of ergonomics and fatigue study. (A number of Gilbreth photos can be found in an outstanding 1989 book, Mike Mandel's *Making Good Time*, published by the California Museum of Photography at the University of California, Riverside.)

Another researcher, Frederick W. Taylor, was instrumental in time studies of work. Although I wrote a book on Taylor, my ''heroes'' are the Gilbreths, for they brought a warmth to engineering. The bad blood that existed in later years between Taylor and the Gilbreths is not mentioned, nor even hinted at. Lillian was much above that.

The book was first published around 1925, after Frank's untimely, but not unanticipated, death on July 14, 1924. My original copy was signed by Lillian and presented to Taylor's widow. This early printing, however, appears to have been quite limited; few libraries have copies and it rarely turns up in used-book stores. A reprinting was issued in the early 1950s, and in 1972, the now-dormant Hive Press offered another reprint; both also had very limited runs. This latest reprint was made possible by Yisrael Martin of Hive Press and the Society of Women Engineers in New York City.

There's no doubt about it: this book is a love story, and it's fun to read. However, it is not the humorous account of the Gilbreth's work found in *Cheaper by the Dozen*, *Bells on their Toes*, or *Time Out for Happiness*, stories of the family as seen by two of the gifted children, Ernestine Gilbreth Carey and Frank B. Gilbreth Jr. Nor is it the story of Lillian and Frank's life together; Edna Yost's *Partners for Life* (1949) covered that.

This is Lillian's view of Frank: the engineer, humanitarian, father, and quester. It begins with his early life and his mother's quest for the best life and the best education for her children. Frank did, in fact, pass the entrance examination for the Massachusetts Institute of Technology in Cambridge, but decided to go to work instead. His first day on the job, as a ''gofer'' at a construction site, he noticed six ways of laying bricks—a remarkable perception for a boy just five days past his 17th birthday.

After 10 years learning the construction trade, Frank branched out on his own on April Fool's day, 1895. First it was the construction business, then it was scientific management, then writing, and then consulting and more writing. But always he was on a quest

Books

for the "one best way" to do work. Books were written, business worked its ebb and flow, Frank consulted and interacted with the great pioneers of scientific management, and it's all mentioned in Lillian's account.

Far from being a narrowing influence, the one best way proved expansive, according to Lillian, partly because it so strongly emphasized "likenesses. It took plant problems in the production end, in the selling end, in the office end, in the financial end, everywhere throughout the plant and showed [them to be] alike."

The quest was also to make the family the one best family. Lillian noted that "as the children grew older, they began to have their own ideals, their own goals, and to look forward to their own Quests. This, too, brought valuable lessons. It is so easy to feel that only your life work is truly fascinating; that what you see to be the best and most beautiful is best and most beautiful for everyone.... The One Best Way...is a universal possession. It has individuality. It changes. It grows."

Ronald G. Greenwood is the F. James McDonald chaired professor of industrial management at GMI Engineering and Management Institute in Flint, Mich. He is chair of the management history division of the Academy of Management, Mississippi State University, Miss. He recently coauthored Frederick Taylor, Father of Scientific Management: Myth and Reality, *published by Business One Irwin, Homewood, Ill.*

Coordinator: Glenn Zorpette

Recent books

Handbook of Quality Integrated Circuit Manufacturing. *Zorich, Robert*, Academic Press, San Diego, Calif., 1991, 583 pp., $89.95.

Introductory Electronic Devices and Circuits: electron flow version, 2nd edition. *Paynter, Robert T.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 1031 pp., $50.67.

Fiber Optic Sensors: an introduction for engineers and scientists. Ed. *Udd, Eric*, John Wiley & Sons, Somerset, N.J., 1991, 476 pp., $69.95.

The 68000 and 68020 Microprocessors: architecture, software, and interfacing techniques. *Triebel, Walter A.*, and *Singh, Avtar*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 477 pp., $54.

Lotus 1-2-3/G: simplified. *Bolocan, David*, Windcrest Books, Blue Ridge Summit, Pa., 1991, 348 pp., $22.95.

Digital Signal Processing: efficient convolution and Fourier transform techniques. *Myers, D.G.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 355 pp., $45.

Beginner's Guide to Reading Schematics, 2nd edition. *Traister, Robert J.*, and *Lisk, Anna L.*, Tab Books, Blue Ridge Summit, Pa., 1991, 129 pp., $10.95.

Digital Signal Processing Applications: using the ADSP-2100 family. Ed. *Mar, Amy*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 611 pp., $46.

An Introduction to Modern Electronics. *Faissler, William L.*, John Wiley & Sons, Somerset, N.J., 1991, 512 pp., $57.95.

Digital Signal Processing Applications: with the TMS320 family, Vol. 3. Ed. *Papamichalis, Panos E.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 561 pp., $48.

Introduction to Electricity and Electronics: electron flow version, 3rd edition. *Mottershead, Allen*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 771 pp., $51.

Calendar

(Continued from p. 8)

Data Compression Conference (C); March 24–27; Cliff Hotel, Snowbird, Utah; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Position, Location and Navigation Symposium—Plans '92 (AES); March 24–27; Doubletree Hotel, Monterey, Calif.; Thomas E. Sanders, 160 Clover Circle, Southampton, Pa. 18966; 215-441-2350.

Princeton Section Sarnoff Symposium (LEO, MTT et al.); March 27; David Sarnoff Research Center, Princeton, N.J.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

International Reliability Physics Symposium (ED); March 30–April 2; Town and Country Hotel, San Diego, Calif.; Harry Schafft, National Institute of Standards and Technology, Building 225, Room B360, Route 270, Quince Orchard Road, Gaithersburg, Md. 20899; 301-975-2234; fax, 301-948-4081.

International Symposium on Parallel Processing (C); March 30–April 2; Beverly Hilton Hotel, Beverly Hills, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

IEEE/ASME Joint Railroad Conference (VT); March 31–April 2; Atlanta Hilton and Towers, Atlanta, Ga.; Joseph Castellani, AEG Westinghouse, 1501 Lebanon Church Rd., Pittsburgh, Pa. 15238; 412-655-5270.

APRIL

11th Annual International Phoenix Conference on Computers and Communications (C, COM); April 1–3; Wyndham Paradise Valley Resort, Scottsdale, Ariz.; Joseph Urban, Department of Computer Science and Engineering, College Engineering and Applied Science, Arizona State University, Tempe, Ariz. 85287-5406; 602-965-2774; fax, 602-965-2751.

12th International Electronic Manufacturing Technology Symposium (CHMT); April 1–3; Congress Centrum Mainz, Mainz, Germany; Conference Secretariat, IEMT 1992, c/o CTI GmbH, Nymphenburger Strasse 88, D-8000 Munchen 19, Germany; (49+89) 129 2003; fax, (49+89) 129 2009.

Network Operations and Management Symposium (COM); April 6–9; Peabody Hotel, Memphis, Tenn.; Jill Pancio, Pacific Bell, 7620 Convoy Court, San Diego, Calif. 92111; 619-268-6135; fax, 619-292-1509.

Southeastcon '92 (Region 3 et al.); April 12–15; Wynfrey Hotel, Birmingham, Ala.; Wayne Owen, South Central Bell, 600 N. 19th St., Birmingham, Ala. 35203; 205-321-2299.

Intermag '92 (MAG); April 13–16; Adams Mark Hotel, St. Louis, Mo.; Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-5088.

International Conference on Computer Languages (C); April 20–23; Cathedral Hill Hotel, San Francisco; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Fourth International Conference on Indium Phosphide and Related Materials (ED); April 21–24; Newport Sheraton,

Calendar

Newport, R.I.; Susan Evans, IEEE/LEOS Executive Office, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3896; fax, 908-562-1571.

Seventh Conference on Semi-Insulating III-V Materials (ED); April 21–24; Krystal Hotel, Ixtapa, Mexico; William Ford, Harris Microwave Semiconductor, 1530 McCarthy Blvd., Milpitas, Calif. 95035; 408-433-2222; fax, 408-432-3268.

Electrical Performance of Electronic Packaging (CHMT, MTT); April 22–24; Holiday Inn, Tucson, Ariz.; Paul Baltes, Engineering Professional Development; Harvil Building, Box 9, University of Arizona, Tucson, Ariz. 85721; 602-621-5104; fax, 602-621-1441.

Workshop on Workstation Operating Systems—WWOS-III (C); April 23–24; Sheraton Royal Biscayne, Key Biscayne, Fla.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Scalable High Performance Computing Conference (C); April 26–29; Williamsburg Hilton and National Conference Center, Williamsburg, Va.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

MAY

Custom Integrated Circuits Conference—CICC '92 (ED); May 3–6; Westin Copley, Boston; Laura Morihara, Convention Coordinating, 47-344 Waihee Rd., Kaneohe, Oahu, Hawaii 96744; 808-239-4790.

Industrial and Commercial Power Systems Technical Conference (IA et al.); May 4–7; Sheraton-Station Square Hotel, Pittsburgh; Dave Shipp, Westinghouse Corp., 750 Trumbull Dr., Pittsburgh, Pa. 15205; 412-429-7430.

International Conference on Computer Systems and Software Engineering—Compeuro '92 (C, Region 8 et al.); May 4–7; Netherlands Congress Center, The Hague; P.M. Dewilde, Delft University of Technology, Department of Electrical Engineering, Mekelweg 4, 2628 CD Delft, The Netherlands; (31+15) 7850 89.

Infocom '92 (C, COM); May 4–8; Congress Center, Florence, Italy; Maurizio Decina, Consorzio Cefriel, Viale Sarca 202, 20126 Milan, Italy; (39+2) 661 00083; fax, (39+2) 661 00448.

Fifth IEEE Workshop on Metropolitan Area Networks (COM); May 10–13; Hotel Capo Taormina, Taormina, Italy; Luciano Lenzini, CNUCE, 36 Via S. Maria, 56100 Pisa, Italy; (39+50) 593 245.

International Symposium on Circuits and Systems—ISCAS '92 (CAS); May 10–13; Sheraton Harbor Island Hotel, San Diego, Calif.; Stanley A. White, 433 E. Avenida Cordoba, San Clemente, Calif. 92672; 714-498-5519.

International Conference on Robotics and Automation (RA); May 10–15; Acropolis Convention Center, Nice, France; Harry Hayman, Box 3216, Silver Spring, Md. 20918; 301-236-5621; fax, same number; 301-236-5621 after March 31.

Microwave Power Tube Conference (ED); May 11–13; Naval Postgraduate School, Monterey, Calif.; Ralph Nadell, Palisades Institute, 201 Varick St., New York, N.Y. 10014; 212-620-3341; fax, 212-620-3379.

Vehicular Technology Conference (VT, Denver Section); May 11–13; Regency Hyatt Hotel, Denver, Colo.; Jim Schroeder, Department of Engineering, University of Denver, 2390 S. York St., Denver, Colo. 80208-0177; 303-871-3519.

Electro '92 (Region 1 et al.); May 12–14; Hynes Convention Center, Boston; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-215-3976; fax, 800-877-2668.

Instrumentation and Measurement Technology Conference (IM et al.); May 12–14; Meadowlands Hilton Hotel, Secaucus, N.J.; Robert Myers, 3685 Motor Ave., Suite 240, Los Angeles, Calif. 90034; 213-287-1463; fax, 213-287-1851.

International Symposium on Semiconductor Manufacturing Technology—ISSMT '92 (ED); May 14–15; The Hotel New, Otani, Japan; Tadahiro Ohmi, Tohoku University, Department of Electronics, ASA-Aoba, Aramaki, Sendai 980, Japan; fax, (081) 022 224 2549.

Symposium on Worldwide Advances in Communication Networks (COM); May 14–15; George Mason University, Fairfax, Va.; Telecommunications Laboratory, ECE Department, George Mason University, Fairfax, Va. 22030-4444; 703-993-1566; fax, 703-993-1521.

42nd Electronic Components and

(Continued on p. 12H)

Calendar

(Continued from p. 12D)

Technology Conference (CHMT); May 18–20; Sheraton Harbor Island Hotel, San Diego, Calif.; Peter J. Walsh, Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, D.C. 20006-1903; 202-457-4932.

Conference on European Electrotechnology in a Worldwide Market—Eurocon '92 (COM, Region 8); May 18–21; Congress Centre, Zurich; A. Kundig, TIK, ETH-Zentrum, ETZ G 84, CH-8092, Zurich, Switzerland.

National Aerospace and Electronics Conference (AES/Dayton Sec.); May 18–22; Dayton Convention Center, Dayton, Ohio; Sue Brown, ASD/ENES, Wright-Patterson Air Force Base, Ohio 45433-6503; 513-255-6281.

National Telesystems Conference (AES, NCAC); May 19–20; George Washington University, Ashburn, Va.; Talbot S. Huff Jr. or Sally Spooner, E-Systems Inc., Melpar Division, 7700 Arlington Blvd., Falls Church, Va. 22046; 703-849-1500.

Fourth International Symposium on Power Semiconductor Devices and ICs (IEE Japan, ED); May 19–21; Waseda University, International Conference Center, Shinijuki-ku, Tokyo; Hiromichi Ohashi, Electron Devices Laboratory, Toshiba R&D Center, 1, Komukai Toshiba-cho, Saiwai-ku, Kawasaki, 210, Japan; (81) 44 549 2063; fax, (81) 44 555 2074.

International Geoscience and Remote Sensing Symposium (GRS); May 26–29; South Shore Harbour Resort and Conference Center, League City, Texas; Tammy I. Stein, HARC/STAR, 4800 Research Forest Dr., The Woodlands, Texas 77381; 713-363-7922.

36th International Symposium on Electron, Ion, and Photon Beams (ED); May 26–29; Peabody Hotel, Orlando, Fla.; Randy Kubena, Hughes Research Laboratories, 3011 Malibu Canyon Rd., Malibu, Calif. 90265; 310-317-5423; fax, 310-317-5840.

46th Annual Symposium on Frequency Control (UFFC); May 27–29; Hershey Lodge and Convention Center, Hershey, Pa.; Raymond L. Filler, U.S. Army ETDL, SLCET-EQ, Fort Monmouth, N.J. 07703-5601; 908-544-2467.

Workshop on Numerical Modeling of Processes and Devices For Integrated Circuits–Nupad IV (ED); May 31–June 1; Westin Hotel, Seattle, Wash.; Fely Barrera, Stanford University, 205 AEL Building, Stanford, Calif. 94305-4055; 415-723-4138; fax, 415-725-7298.

JUNE

19th International Conference on Plasma Sciences (NPS); June 1–3; Hyatt Regency Westshore Hotel, Tampa, Fla.; Norman L. Oleson, Department of Electrical Engineering, Eng 118, University of South Florida, Tampa, Fla. 33620; 813-974-2369; fax, 813-974-5250.

Symposium on Autonomous Underwater Vehicle Technology (OE); June 2–3; Dulles Airport Marriott Hotel, Washington, D.C.; Gordon Raisbeck, 40 Deering St., Portland, Me. 04101-2212; 207-773-6243.

International Microwave Symposium (Microwave Theory and Techniques); June 2–4; Albuquerque Convention Center, Albuquerque, N.M.; Everett Farr, BDM Corp., 1801 Randolph Rd., S.E., Albuquerque, N.M. 87106; 505-848-5000.

Circle No. 29

Calendar

VLSI Technology Symposium (ED); June 2–4; Westin Hotel, Seattle, Wash.; James Clemens, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, N.J. 07974; 908-582-2800.

Second International Symposium on Atomic Layer Epitaxy (ED); June 3–5; Raleigh Marriott, Raleigh, N.C.; Salah M. Bedair, Department of Electrical Engineering, North Carolina State University, Raleigh, N.C. 27695-7911; 919-515-5704; fax, 919-515-3027.

Workshop on Combinations of Genetic Algorithms and Neural Networks (NN); June 6; Sheraton Inn Harbor, Baltimore, Md.; J. David Schaffer, Phillips Laboratories, 345 Scarborough Rd., Briarcliff Manor, N.Y. 10510; 914-945-6168.

International Symposium on Electrical Insulation (DEI); June 7–10; Omni Inner Harbor Hotel, Baltimore, Md.; D. Randy James, Oak Ridge National Laboratory, Box 2008, Building 3147, MS-6070, Oak Ridge, Tenn. 37831-6070; 615-574-0266/6213.

Fifth Human Factors and Power Plants (PE); June 7–11; Marriott Hotel, Monterey, Calif.; Robert Starkey, B&W Nuclear Service, 3315 Old Forest Rd., Lynchburg, Va. 24501; 804-385-2905.

International Joint Conference on Neural Networks (NN); June 7–11; Baltimore Convention Center, Baltimore, Md.; Nomi Feldman, Meeting Management, 5665 Oberlin Dr., Suite 110, San Diego, Calif. 92121; 619-453-6222.

Pulp and Paper Industry Conference (IA); June 8–12; Portland Marriott, Portland, Ore.; Edward Kayfes, Harris Group Inc., 1750 N.W. Front Ave., Box 5819, Portland, Ore. 97228; 503-228-7200; fax, 503-228-0422.

Sixth International Conference on Metalorganic Vapor Phase Epitaxy (LEO); June 8–12; Hyatt Cambridge, Cambridge, Mass.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

29th ACM/IEEE Design Automation Conference (C, CAS); June 8–12; Anaheim Convention Center, Anaheim, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Conference on Precision Electromagnetic Measurements (IM); June 9–12;

Calendar

CNIT Paris la Defense, Paris, France; Jean Blouet, Bureau National de Metrologie, 22 Rue Monge, F-75005 Paris, France; (33+1) 46 34 4840; fax, (33+1) 46 34 4863.

Symposium on Computer-Based Medical Systems (C, EMB); June 14–17; Washington Duke Inn and Golf Club, Durham, N.C.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Conference on Communications—ICC/Supercomm '92 (COM, Chicago Section); June 14–18; Chicago Hilton and Towers, Chicago; P. Douglas Lattner, Ameritech Services, 2000 W. Ameritech Center Dr., Hoffmans Estate, Ill. 60196-1025; 708-248-5302; fax, 708-248-3977.

International Semiconductor Manufacturing Science Symposium (ED); June 15–17; Moscone Convention Center, San Francisco; Corinne Cargnoni, SEMI, 805 E. Middlefield Rd., Mountain View, Calif. 94043; 415-940-6950.

Fourth International Conference on Software Engineering and Knowledge Engineering (C); June 17–19; Europa Palace Hotel, Capri, Italy; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Solid-State Sensor and Actuator Workshop (ED); June 21–25; Marriott Hilton Head Resort, Hilton Head Island, S.C.; Steve Senturia, Massachusetts Institute of Technology, Room 39-567; Department of Electrical Engineering, Cambridge, Mass. 02139; 617-253-6869; fax, 617-253-9606.

International Workshop on Hardware Fault-Tolerance in Multiprocessors (C); June 22–23; University of Massachusetts, Amherst; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

50th Annual Device Research Conference (ED); June 22–24; Massachusetts Institute of Technology, Cambridge, Mass.; Sam Shichijo, Texas Instruments Inc., 12840 Hillcrest, Suite 200, Dallas, Texas 75230; 214-917-7402.

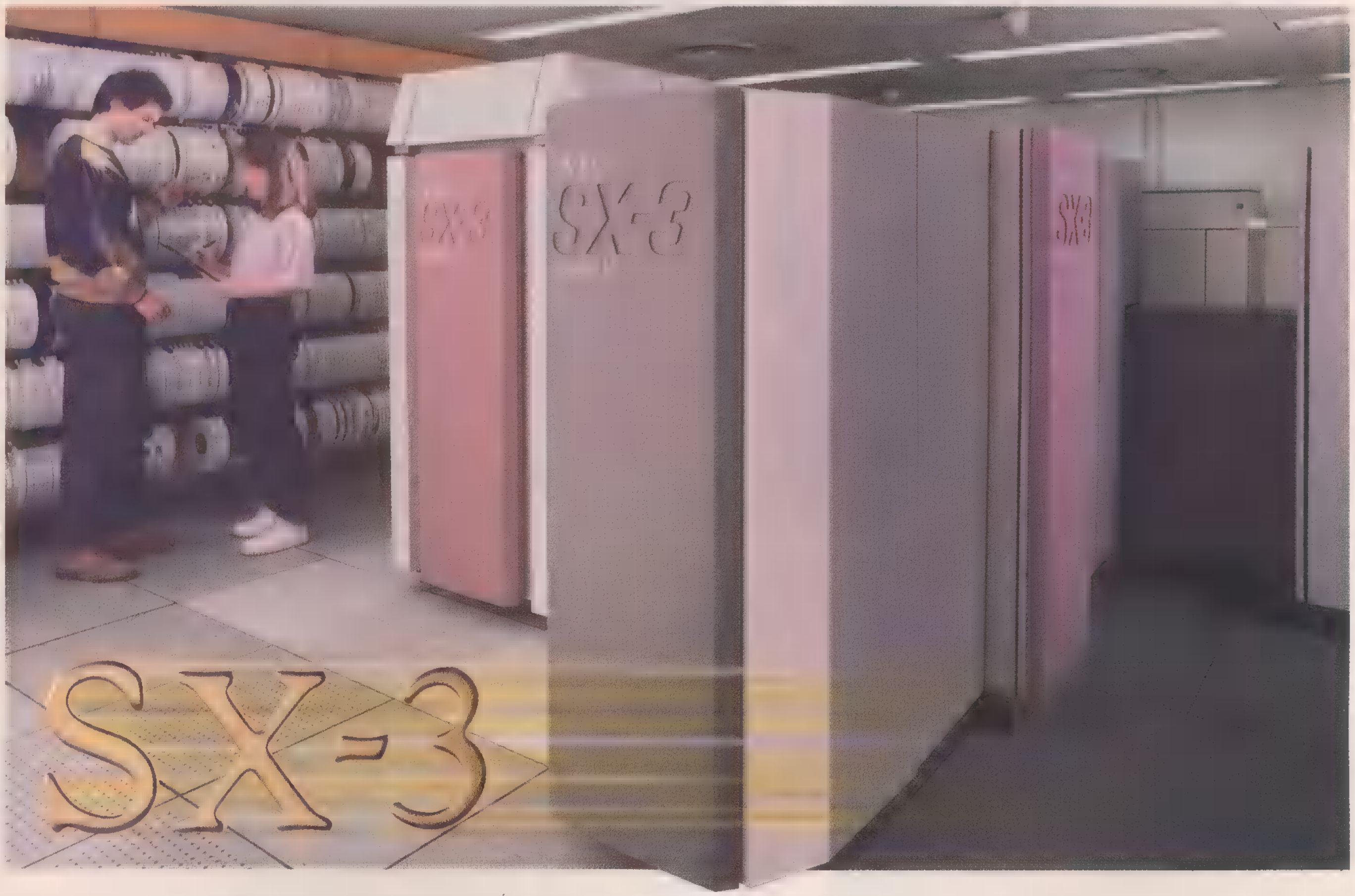
20th Power Modulator Symposium (ED); June 23–25; Myrtle Beach Hilton Hotel, Myrtle Beach, S.C.; Mark Goldfarb, Palisades Institute, 2011 Crystal Dr., Suite 307, Arlington, Va. 22202; 703-769-5588.

American Control Conference (CS); June 24–26; Westin Hotel, Chicago; Dale Seborg, Chemical and Nuclear Engineering, University of California, Santa Barbara, Calif. 93106; 805-961-3352.

JULY

Fifth International Vacuum Microelectronics Conference (ED); July 13–17; Hotel Chateau Wilhelminenberg, Vienna, Austria; Johannas Mitterauer, Technical University of Wien, Institut für Allgemeine, Elektrotechnik und Elektronik, Gusshausstrasse 27–29, A-1040 Wein, Austria; (43+1) 588 01 3682; fax, (43+222) 505 2666.

Nuclear and Space Radiation Effects Conference (NPS); July 13–17; Hyatt Regency Hotel, New Orleans, La.; James R. Schwank, Sandia National Laboratories, Division 1332, Box 5800, Albuquerque, N.M. 87185; 505-844-2150; fax, 505-846-5004.



SUPERCOMPUTER STARTS UP AT THE UNIVERSITY OF COLOGNE.

An NEC supercomputer — SX-3 Model 11 — has just started service at the University of Cologne, Germany. The supercomputer system integrates resident LANs, mainframe computers, workstations and terminals. With 1.37GFLOPS speed, the SX-3 Model 11 is serving as a powerful core for inter-collegiate scientific computing services.

The SX-3 Series of supercomputers includes eight models ranging from a single-processor type with 0.68GFLOPS speed to the top-end, 4-processor 22 GFLOPS model. The world-class speed of SX-3 Series supercomputers comes from advanced system architecture, VLSIs with 70 picosec gate switching speed and high-density packaging.

The SX-3 Series supports the SUPER-UX operating system — a sophisticated UNIX-based OS designed for multiprocessor supercomputer applications. Extended functions for supercomputing permit efficient program development and the use of a wide variety of applications software.

Recent orders for the SX-3 Series include a 2.75GFLOPS Model 12 to the National Aerospace Laboratory, the Netherlands; and a two-processor, 5.5GFLOPS Model 22 to the Swiss Scientific Computer Center.

UNIX: Registered trademark of UNIX System Laboratories, Inc. in the U.S.A. and other countries.

NUMBER 146

2.4G OPTICAL TRANSMITTER/ RECEIVER MODULES.

NEC is now offering transmitter/ receiver modules for 2.4Gbps fiber optic transmission systems—vital trunk lines of global-standard SDH/SONET digital networks.

Transmitters are available for 1.3μm and 1.55μm wavelengths. The 1.3μm NDL5803P and 1.55μm NDL5853P are both distributed feedback (DFB) laser diode modules with single mode fiber pigtails.

The DFB laser diodes provide extremely stable oscillation in a single longitudinal mode because they feature a unique diffraction grating and a double-channel planar buried heterostructure (DC-PBH). Both modules incorporate an optical isolator to reduce reflection noise. Matching impedance is 50 or 25 ohms.

These transmitters mate with two matching receivers. The NDL5520P and 5522P are InGaAs avalanche photo diode modules featuring extremely high sensitivity and a wide dynamic range. The NDL5522P incorporates a pre-amplifier IC.

NEAX61 ATM BROADBAND SWITCH FOR SMDS.

Switched Multimegabit Data Service (SMDS) is a public high-speed, packet-switched, connectionless data service now emerging in the U.S. A stepping stone to broadband ISDN and synchronous optical networks, SMDS uses fiber lines to connect far-flung LANs, workstations and host computers.

The NEAX61 SMDS Service Node employs a high-speed, Asynchronous Transfer Mode (ATM) switching platform to offer efficient connectivity over wide areas at speeds up to 45Mbps. The ATM switching platform uses 155.52 or 622.08Mbps transmission paths to break data down into 53-byte "cells." The system multiplexes and switches these information packets at high speeds. The SMDS Service Node is ideal for networks integrating high-resolution image communication and high-speed data transmission.

The NEAX61 SMDS Service Node supports a wide variety of broadband applications, including joint medical diagnoses during which experts at different facilities can view and discuss X-Ray and CT-scan images. Our SMDS Service Node is compatible with current networking environments and such future developments as B-ISDN.

SMDS: Service mark of Bell Communications Research Inc.

FIRST SUB-MICRON, CELL-BASED ASICs.

NEC's new cell-based ASICs offer more speed, more functions, and higher integration to help designers reach the goal of putting "a system on a single chip."

Our CB-C7 series ASICs use a 0.8μm CMOS process to offer 0.33ns power gate delays*, 6.5μW/gate/MHz power dissipation and up to 180K-gate densities. Operating voltages are from 3 to 5V.

*F/O=2, l=2mm

Megafunctions include: 8088- and 8086-compatible CPU cores (the V20H and V30H respectively); intelligent peripherals such as FDC, GDC and DMAC. RAM and ROM capacities can be customized to meet system needs. For fast turnaround, user-defined logic can be implemented in a sea-of-gates array. To minimize chip cost, the entire ASIC is fabricated with standard cell technology.

The CB-C7 series is supported by our OpenCAD Design System™, a complete front-to-back-end unified design environment. For greater convenience, designers can use most popular workstations and their favorite CAD tools to design cell-based CB-C7 ASICs.

Forum

Risk and reason

I am not at all sure I understand what M. Granger Morgan's review of *Technological Risk* [November, p. 11] is trying to say. He devotes 10 paragraphs to criticizing [author Harold W.] Lewis for his failure to reference social science research on risk perception and then dismisses "the best part of the book" (about half of it) in one paragraph.

While the results of risk perception research are intellectually interesting, I am not sure what, if any, value it adds to determining public, or for that matter private, policy. For example, I can find all kinds of good reasons based on equity, personal control, knowledge, and immediacy for not using my seat belt, but I still hook it up each time I get into a car. Such reasoning seems to me to be counting on luck, and yet Morgan agrees that we should not do this.

As an attorney for the Natural Resources Defense Council argued about Alar on apples: if a person perceives something as a risk, then it is a risk. Is that the kind of thinking we should be using? There is a lot of sloppy thinking in our society today, and Lewis' book should help in clearing up some of that; the social sciences are only clouding the issues.

M. F. Moon
Orange, Calif.

M. Granger Morgan replies:
Moon begins by saying "I am not at all sure I understand what Morgan's review . . . is trying to say" and closes by observing "...there is a lot of sloppy thinking [about risk] in our society today . . . the social sciences are only clouding the issues." What my review was trying to say is that the latter is not true, and it is unfortunate that Lewis' book did not do as much as it might have to help readers like Moon understand why.

How to succeed in business

In days of yore, software engineers were praised and promoted for writing and debugging code. Times change. Today, in my department, only the weaker performers write code; the more talented and ambitious of us get ahead by making presentations with Vugraphs.

Since they are so crucial to career success, Vugraphs deserve to be studied more formally. Why don't engineering schools have departments of Vugraph engineering? Their students would have a leg up in the real world. Courses would include: The Importance of Vugraphs in Presentations, Projector Operations, Pleasing Your Boss, Pleasing Your Boss's Boss, Making Your Boss's Enemies Look Bad, Vugraph Hardware, Presentation Software, Vugraph Layout and Design, and Vugraph Management.

Many talented engineers are passed over for promotion because of their weak Vugraphs. Engineering schools could reverse the tide by teaching Vugraph presentation skills to new and existing engineers.

David Levner
Rego Park, N.Y.

Working in the real world

Robert Lucky's "Reflections" [November, p. 6] struck a chord, one that has concerned me since my graduation from college in 1978. He asked the rhetorical question, "What's real anymore?," and lamented the intrusion of software into real-world educational labs.

One aspect of electrical engineering, however, is still very much hands-on, and will continue to be so for quite some time. This area, increasingly neglected by the educational community, is power engineering.

My real lament is that this most fundamental of electrical engineering disciplines has gradually lost its appeal to students, primarily because it is commonly viewed as a mature technology and therefore has seen its support continually decrease. Many fine universities have even dropped their power engineering program.

Electrical engineers can now graduate without ever having been exposed to even the most basic tenets of power system engineering. One result of this lack of exposure is that the electrical utility industry and its suppliers are being confronted with an ever-decreasing pool of qualified young engineers who could fill the gaps left by attrition, not to mention new positions as they arise.

Lucky concludes his column with a summary of a virtual world, with everything being done by mirrors. While this may be ever more the case in the areas dominated by software and semiconductors, silicon and program code will never be able to produce or transmit the vast amounts of energy required to support our daily life. Software is already very valuable in the engineering, operation, and control of power systems, but electromagnetic devices (generators and transformers), conductors, and insulators are still very much not virtual.

Many of the traditions in the power system industry are changing, offering plenty of opportunities to apply new technology to the generation, transmission, conservation, and control of energy. With social and environmental issues making it increasingly difficult for utility companies to construct new power plants and transmission lines, this seemingly mature field is going through a quiet rebirth.

There are many bright students who wish to study electrical engineering, but also have a knack or desire for hands-on application of technology. I encourage these students to consider a career in power systems engineering, a field that has many opportunities for those who wish to "make a difference." Not only will they find interesting challenges, but also they will find themselves to be part of a relatively small group of young engineers in an important career field. Perhaps more crucial, though, is that they will be making valuable contributions to the production and delivery of the energy that drives not only our economy but our daily lives as well.

Charles W. Rogers
Jackson, Mich.

Addendum

On p. 37 of the February issue, the "To probe further" [of the boundary-scan article] should have included the IEEE Educational Activities videotape VC 28, "Chip to System Testability Access," broadcast March 1, 1989. The videotape is available in PAL or NTSC format. *—Ed.*

Correction

On p. 38 of the January issue, the titles of the two bar charts were reversed. The top chart actually shows the world's top 10 telecommunications services companies (64 percent of the market); the bottom chart shows the world's top 10 telecommunications equipment makers (73 percent of the market). *—Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contacts: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453. The Compmail address is ieeespectrum. The computer bulletin board number is 212-705-7308 and the password is SPECTRUM; for more information, call 212-705-7305 and ask for the Author's Guide.

CommNexus

Presents

The LiSBUS™ Async I/O System

A solution of the 1990's for today's data transmission problems.

Outstandingly Simple and Reliable because **LiSBUS**tm is based on a breakthrough technology which uses the impedance of the bus cable to replace binary addresses. Consequently, data transmission management is greatly simplified and much more reliable than today's equivalent systems which require expensive software, hardware, and personnel investments.

Outstandingly Practical because it is easy to install and operate. No special tools, workbench, or electronics expertise are needed. Anyone can be up and running in minutes. Just plug in the external modules and configure the system with the user-friendly **LiSBUS**tm **Link Control Software**. Each external module measures only around 2in. by 2in.

Outstandingly Flexible because a user can connect up to 60 peripherals or computers to a controlling computer through their RS-232C (COM) ports. To add peripherals, just extend the bus cable and add modules.

At an Unbeatable Price because at $650* for the **LiSBUS**tm **Starter Pack**, no alternative offers all these advantages combined into one product without spending a much higher amount. The **Starter Pack** includes all the user needs to connect four peripherals and a complete set of **LiSBUS**tm **Software Development Tools** to create custom applications.

LiSBUStm **Async I/O System:** A product of our **CommNexus**tm line of communication systems. GIGATEC is committed to offering products and servicing its customers in the best tradition of Swiss quality. We provide our customers with:

- **Technical Support.** Registered buyers can obtain technical support from our qualified engineers.
- **Users and Developers Group.** Organized for encouraging software developments using the products of the **CommNexus**tm family.

For more information and ordering contact:

In the USA and Canada:

Toll Free (800) 945-3002
(excl. Hawaii)
Mon.-Fri. 9am - 9pm EST

GIGATEC (USA), Inc.
871 Islington Street
P.O. Box 4705
Portsmouth, NH 03802-4705 USA
Tel. (603) 433-2227
Fax (603) 433-5552

In Europe:

GIGATEC SA
Ch. des Plans-Praz
1337 Vallorbe SWITZERLAND
Tel. 41 21 843 37 36
Fax 41 21 843 33 25

* specifications and prices subject to change without prior notification

Visa and MasterCard/EuroCard accepted. - CommNexus™ and LiSBUS™ are trademarks of GIGATEC SA.

Circle No. 5

Speakout

Scientific savvy urged on State

Calling scientific and technological understanding the prime tools for world leadership in the coming decades, the Carnegie Commission on Science, Technology, and Government in a report in January recommended transforming U.S. Government agencies, especially the State Department, into "more technologically literate navigators." The goal: to exploit rapid technological change and integrate science and technology (S&T) into international affairs. Highlights of the report, Science and Technology in U.S. International Affairs, *follow:*

The U.S. is deeply and irreversibly embedded in the world economy—and in most respects this is an asset. Yet the asset must be clearly related to foreign policies. U.S. international negotiations must continue to build fair "rules of the game" for the development of the technologies that underlie economic competition.

For economic reasons alone, the overall scope of U.S. foreign policy aims has been growing. International trade negotiators in the 1990s must wrestle with dramatically new opportunities. These range from low to high technology, and from food exports to computer chip imports.

In the early 1960s, for example, the combined value of imports and exports was only about 10 percent of gross national product (GNP). By the late 1980s, this had grown to more than 25 percent. Exports exceeded 12 percent of GNP in 1989 and must grow further if the economy is to thrive. Hundreds of thousands of jobs are at stake. Diplomacy dealing with these economic issues inevitably involves understanding the role of technology in the economy.

Military issues will also become more complex in foreign policy. U.S. spending for national security continues at almost US $300 billion per year, and worldwide exports of arms show few signs of abating. The planned sharp decrease in defense spending may call for even more complex integration of defense plans with civilian concerns in foreign policy.

The Defense Department has had 600 bilateral basic research agreements with about 20 countries. It also has co-development agreements worth [up] to hundreds of millions of dollars, and its annual spending on international S&T is $2 billion.

No matter how this activity may change with policy and budget shifts in the next few years, one thing is clear: Desert Storm's lessons about the power of military technology must be applied with subtlety and prudence at the intersection of plans for defense cooperation and foreign policy.

Further, direct military aid to the Third World—about $8 billion currently—will surely change character in the 1990s. Developing countries will more frequently think in terms of trade, finance, and immigration, rather than in terms of East-West geopolitics and military alliances. Astute analysis of high-tech and low-tech arms trading on a global scale will be required, as may entirely new concepts for limiting the arms trade and containing conflicts.

Altogether, the U.S. will spend in 1992 more than $150 billion on research and development, with about 45 percent funded by the federal government. Almost three-quarters of the effort is being carried out by the private sector. But national R&D is being carried out increasingly in an international setting.

Developed countries seek exchanges of (and deals with) each other's R&D. U.S. firms seek alliances with foreign firms and universities are in contact with leading investigators around the world. Developing countries seek cooperation with the United States in every scientific field and especially on the administration of market-competititive R&D enterprises.

To cope with the growing calls for R&D partnerships, State's role in charting foreign policy must include advocating international concerns among government agencies. To do this, State must have more than superficial familiarity with the texture of U.S. science and technology.

Accordingly, the report recommends:

- The President, aided by a year-long inquiry, should clarify the international responsibilities for science and technology among agencies and ensure that they're coordinated with foreign policy through the Department of State. Clear international responsibility for mission-oriented basic science should be given to agencies such as [the] Department of Energy, National Aeronautics and Space Administration, Department of Commerce, and National Institutes of Health, while the National Science Foundation manages many of the international basic science programs.
- Evaluate projects in Big Science and Little Science for their foreign policy implications. Any international mandates given to individual agencies—Commerce, for example—should be regularly assessed, updated, and woven together in order to promote the national interest for the future.
- Define afresh the U.S. international goals

(Continued on p. 20)

Speakout

(Continued from p. 18)

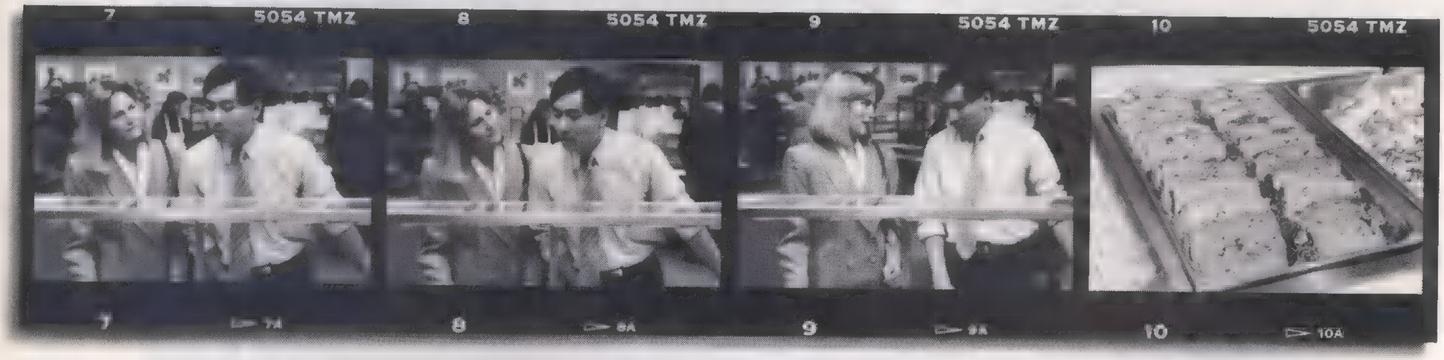
for science and technology; bring increasingly important international programs into the mainstream throughout the S&T agencies of the government; and orchestrate use of the nation's full technical assets to fulfill the goals of American foreign policy.

For example, the nation can't go to meetings of the General Agreement on Tariffs and Trade with multiple viewpoints on selling computers and related services. Agriculture, Energy, the Agency for International Development, and Environmental Protection Agency shouldn't arrive in Brazil for the 1992 United Nations Conference on Environment and Development with "independent" U.S. positions.

- Take steps to ensure that State Department officials have a lively awareness of S&T in planning foreign policy, administering diplomatic operations, and facilitating initiatives by the mission agencies. A new post, a Science and Technology Counselor reporting to the Secretary, should be created with functions comparable to the President's Science Advisor (whose position and office should be strengthened). Several S&T-related sectors and long-range planning should be consolidated under an Under Secretary for Economic and S&T Affairs. The number of Science Officers at embassies abroad must be increased—only about 25 missions now have full-time S&T staff.
- Set plans for the long-term nurturing of human resources throughout the government for work on global issues with a substantial scientific and technological character. In the State Department, this will require more aggressive recruiting of officers with technical backgrounds, more flexible exchanges with industry and universities, and incentives for careers in international S&T. A single International Science Service for all agencies might be created within the federal career structure.
- Increase the external research budget and advisory resources available to the President's Office of Science and Technology Policy, State, and other agencies for identifying those functions of foreign policy requiring technical expertise. Alone among the major agencies, State has no external intellectual infrastructure to assist its planning on a regular basis. State's present, almost moribund, Science and Technology Advisory Committee, must be invigorated.

The Carnegie Commission on Science, Technology, and Government, New York City, was created in April 1988 by Carnegie Corp. of New York to help government institutions respond to advances in science and technology. It does this by sponsoring studies and seminars and setting up task forces to focus on specific issues.

"So you're testing a prototype already?" *"Yep. Mmm, lasagne."* "Patents checked?"



"Wouldn't test otherwise." "Meet industry standards?" *"It'll comply…*

…which I don't think is true of the meatloaf." "Say, where're you getting so much help, anyway?"

The answer is in Dialog.

Information—complete, precise, up-to-the minute. It's your most powerful research tool. Find exactly what you need to know fast in Dialog® the world's first and largest electronic library. We offer over 400 diverse, detailed databases readily accessible online via computer and modem, many even on compact disc. You probably won't have to look anywhere else. See your company's Information Specialist about Dialog. Or call for a free kit on Dialog information for your industry.

1-800-3-DIALOG

Outside U.S., 415-858-3785. Fax 415-858-7069.

Dialog Engineering Tools: Research and industry news for computers, electronics, energy, materials, and more. Plus patent, trademark, safety, regulatory, competitive data. Full text and/or abstracts from newspapers, newsletters, journals, proceedings, handbooks, encyclopedias. Some sources updated as often as daily, even continuously.

DIALOG INFORMATION SERVICES, INC.
A KNIGHT-RIDDER COMPANY

Q415

Circle No. 3

Spectral lines

MARCH 1992 Volume 29 Number 3

Design, don't build?

Whatever other advanced nations may do in the wake of the cessation of the cold war, the United States has declared its intention to remain technically prepared to retain its position as the strongest world power—ready to defend itself and other countries if necessary to limit the spread of aggression. At the same time, a peace dividend, wanted in the United States and needed even more desperately in East European countries, should come from decreased spending for the military.

One way to do this, favored by the U.S. Department of Defense (DOD) and the current administration, is to curtail spending on the production of existing weapons but to retain programs to design, but not build, future systems. Some think this is fraught with hazards and foreboding implications.

For one thing, the "design, don't build" concept is nearly diametrically opposed to the DOD-endorsed concept of concurrent engineering, in which the processes by which a system is to be built are considered and developed in parallel with its design. Concurrent engineering depends upon designing, developing, testing, and building prototype parts and subsystems concurrently, not serially, while at the same time designing and developing the equipment to fabricate the new design. A prime objective of concurrent engineering is shortening the time from conception to deployment (or to market in the case of ■ commercial development), so as to be more competitive (either in military preparedness or in the international commercial marketplace).

With "design, don't build," a completed but shelved design may, by the time it is considered for manufacture, be obsolete because of advances in manufacturing tools and techniques. Then who (or what) will serve as the corporate design memory to quickly and efficiently update the design? Even the best documentation of ■ design cannot replace ■ design team's collective experience and awareness of all its nuances. Once dispersed, such a resource is all but impossible to retrieve.

An amelioration of that shortcoming would be to periodically update the design. A costly process, it would nevertheless permit incorporating improvements in fundamental design ■■ well as design changes due to improvements in manufacturing technology.

But with "design, don't build," what happens in ■ hot war? Critics respond that the time needed to gear up ■ shelved design for production would be much less if the particular system had been permitted to go to the prototype stage or, even better, to the point of building and fielding ■ few units.

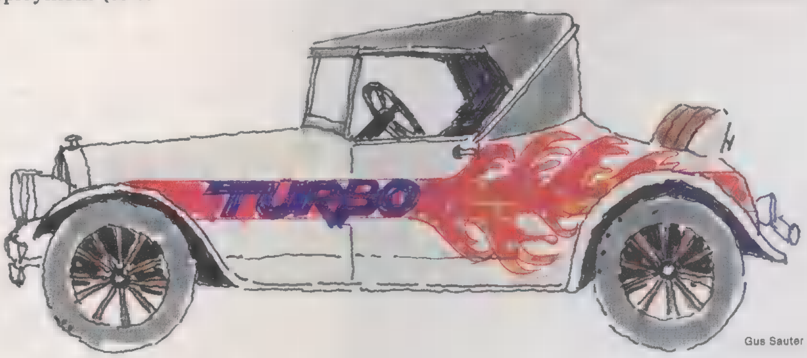
Will the "design, don't build" concept attract those engineers who, seeking perfection and inclusion of the latest technology in all their projects, never want to release them to production anyway? This match—of perfectionist designers with projects that may never be built—may be the ideal marriage. Even so, it may prove difficult for any designer to sustain the high level of enthusiasm that goes with the belief that a design will actually be built.

The viability of "design, don't build" may hinge on where design stops—just how far ■ design is taken. Will any hardware—components, subsystems, or otherwise—be fabricated and tested in field context? Or will "design, don't build" encourage a virtual reality in which ■■ unbuilt system will have to be tested in a simulated environment? For military equipment, this approach would represent war games at their most sophisticated.

One trouble, as the knowledgeable point out, is that real problems often occur at the margin between virtual reality and reality—"the real world." Dramatic historical examples of this can be seen in certain of the National Aeronautics and Space Administration's failures, in which attempts to simulate operational environments did not work. Furthermore, failures often must be experienced before they can be circumvented.

Meanwhile, the gulf between the military and civilian design cultures would widen under "design, don't build," just at the time when concern is greatest about how to shrink the gap.

Donald Christiansen



Gus Sauter

DIGITAL VIDEO

Television, communications, and computer specialists are working to unsnarl the exchange of material in any video format

Seated at his home edu-tainment workstation, Mike Multimedia is researching a report on high-speed rail transportation. In a window on the display he calls up a full-motion color video sequence of a French Train à Grand Vitesse, which he had recorded earlier on a digital laserdisc from a high-definition TV network broadcast. The scenes lack the specific detail he's interested in, so he accesses the international databank in Chicago that stores high-speed rail digital video, and requests additional color sequences. They appear immediately in a second window of the display, but as he is reviewing them, the phone rings and an image of his wife appears in a third window. Her face is flushed, and she is obviously upset. ''Honey, I've had an accident with the car, but I'm not hurt,'' she says, ''but I'm afraid we're going to need a new right front fender.'' Mike answers, ''Don't worry about it, as long as you're O.K.'' Mike, his train of thought broken, is tempted to look in on a football game in a fourth window. After a few minutes, he switches to a full-screen display, and then guiltily goes back to his report. The phone rings again and a fax message from a source appears in another window, containing information to include in the report.

Visionary? Perhaps for now. But video compression, optical-fiber networks, digital recording, digital high-definition television, and the like—the technologies needed for such a scenario—are already in hand. Stirred by an explosion of digital imaging and com-

Ronald K. Jurgen Contributing Editor

0018-9235/92/$3.00©1992 IEEE

munications advances within just the past few years, those involved in TV production, broadcasting, cable, computer graphics and workstations, telecommunications, consumer electronics, you name it, are lining up to make reality serve their dreams.

November 1990 saw one of the first meetings organized so that engineers from various disciplines could debate how best to piece together the emerging world of digital imagery. The sponsors were the Advanced Television Systems Committee and IEEE-USA's Committee on Communications and Information Policy, and the venue was Washington, D.C.

COORDINATION AND HARMONIZATION. The Digital Systems Information Exchange, as it was called, explored digital developments, looked for areas of actual or potential commonality, and examined possible common frameworks for manipulating digital images "at various levels of performance, for a variety of applications, and in a fashion that takes best advantage of current and future developments in television, computers, and communications technologies." So said K.P. Davies, director of standards and technology for the Canadian Broadcasting Corp., Montreal, in his keynote address. Davies emphasized that by now application-dependent developments of digital imaging require "coordination and harmonization if a future coherence is to be achieved."

Gary Demos of DemoGraFX in Culver City, Calif., another participant, also found harmonization desirable in light of the growing use of moving TV imagery on computer screens. Both live analog and compressed digital TV signals in various formats are being applied, he said, in such areas as medical imaging, military applications, aviation and flight control simulation, computer graphics, computer-aided design and engineering, aesthetic styling, and motion picture production.

Demos accordingly stressed the need to design an architecture for high-definition television (HDTV) and high-resolution imaging (HRI) systems that would be scalable, extensible, and open. Scalability he defined as the ability to use a variety of resolutions, temporal rates, colorimetry, and intensity dynamic ranges. In other words, displays designed for one set of those parameters should be able to do a reasonable job of showing images produced at higher or lower values of resolutions, rates, color, and so forth.

Extensibility, according to Demos, referred to the ability of a framework of display formats or standards to embrace new requirements and applications. And an open architecture would support inputs and display parameters with many formats. (Extensibility and open architecture are discussed in some detail in the last article of this special report, p. 28.)

Two further Digital Systems Information Exchange meetings were held in March and September 1991, the latter with the sponsorship of the Society of Motion Picture and Television Engineers (SMPTE) instead of the Advanced Television Systems Committee. By then, the committee's start-up function had become a standards function led by the society, which is based in White Plains, N.Y.

SMPTE's involvement was prompted by the keynote address at the March session. Michael J. Sherlock, president, operations and technical services, National Broadcasting Co. (NBC), New York City, challenged those attending with these words: "We need to find practical solutions. We need agreement on how information can be used to reconstruct images in a form which fits the requirements of the different businesses we are in."

Stanley N. Baron, managing director of technical development, NBC, and then SMPTE engineering vice president, responded by saying that SMPTE would investigate two areas: a protocol for a digital interface header/descriptor to permit digitized images to cross industry and standards boundaries, and a possible hierarchy of standards that would mesh industries' varying display requirements. It was further agreed that the research should be conducted within

Train photos: Rail Europe Inc.

A futuristic edu-tainment display could exhibit in windows, as simulated here, full-motion or still video from a variety of video formats.

Defining terms

CD-ROM XA: a compact-disc ROM extended architecture that specifies an encoding format (adaptive differential pulse code modulation) for storing audio information in a digital format.

CDTV: Commodore Dynamic Total Vision, a multimedia system.

Convertibility: capability of being converted to and from existing standards.

Discrete cosine transform: a form of coding used in most of the current image compression systems to reduce the number of bits that must be transmitted.

Extensibility: the capability of being extended to higher performance.

Huffman coding: a static set of minimum-redundancy integral-length bit strings.

Lossless compression: a means of compressing video data that ensures the data is exactly recoverable with no loss in image quality.

Multimedia: descriptive of the delivery of information that combines different content formats (motion video, audio, still images, graphics, animation, text, and so on).

RGB: red-green-blue. A type of computer color display output signal composed of separately controllable red, green, and blue signals, as opposed to composite video in which signals are combined prior to output.

Scalability: the capability of being placed in a graduated series of performance or resolution parameters.

YUV color system: a color-encoding scheme for natural pictures in which the luminance (Y) and chrominance (UV) are separate.

the standards activities of SMPTE.

With a standardized or universal header/descriptor, any video stream could be recognized by any device, whether a TV receiver, computer, or workstation. One segment of the descriptor would identify the type of video that had been received. If the receiving device contained the right kind of decoders, it could then display the received video. Other parts of the descriptor would specify the size of the data packet and might also include such information as copyright information and decoding algorithms.

The SMPTE Task Force on Headers/Descriptors investigated such factors as the header kernel, appropriate error-correcting codes, and block-length specification, and on Jan. 3 recommended ■ common protocol to the SMPTE Standards Committee for consideration at its meeting on Feb. 6. The SMPTE Task Force on Digital Image Architecture was still, at this writing, weighing an open system scalable to various performance levels and extensible to new technologies and had not yet recommended a structure for a hierarchy of digital standards to facilitate interoperation of high-resolution display systems.

The work on header/descriptors and digital image architecture, when finalized in standards, will expedite the development of products capable of exploiting to the fullest extent the various video formats. In the meantime, the existing standards or drafts of standards are also aiding the cause of interoperability.

There are products now available that perform some of the functions necessary for interoperability. Many of them are based on the standards described in the next section. Selected products are described in the final section.

SPECIAL REPORT / CONSUMER ELECTRONICS

An abundance of video formats

Achieving a universal descriptor and an interformat exchange structure are crucial to the promise of digital imaging

Even as the Digital Systems Information Exchange meetings were being held and task forces from the Society of Motion Picture and Television Engineers (SMPTE) began their work on headers/descriptors and digital image architecture, progress was being made on digital video standards. The three main ones concern still-picture compression, video teleconferencing, and full-motion compression on digital storage media. They have been proposed by the Joint Photographic Experts Group (JPEG), the International Telegraph and Telephone Consultative Committee (CCITT), and the Moving Picture Experts Group (MPEG), respectively. All are lossy techniques.

The JPEG standard is an algorithm for coding still pictures developed under the auspices of the International Organization for Standardization (ISO). CCITT's Recommendation H.261 (also called p×64) specifies a method of communication for visual telephony. Both were described in some detail in the October issue of *IEEE Spectrum* [see To probe further, p. 30].

JPEG is a general-purpose compression standard designed to meet the needs of continuous-tone, still-image applications. It is applicable to such uses as photovideotex, desktop publishing, the graphic arts, color facsimile, newspaper wirephoto transmission, and medical imaging.

Recommendation H.261 (p×64) is a standard for covering the entire channel capacity of the integrated-services digital network (ISDN). The p×64 designation refers to $p \times 64$ kb/s, where p can have any value from 1 to 30. The standard is intended for use in videophone and videoconferencing. If p equals 1 or 2 (due to severely limited available bit rate), only videophone is appropriate. But if p is equal to 6 or more, the available bit rate is higher and more complex pictures can be transmitted.

MPEG FOR FULL-MOTION VIDEO. MPEG, the third digital video standard, can be applied to such storage media as compact-disc ROM (CD ROM), digital audio tape, Winchester disk, and writable optical discs and on such communication channels as ISDN and local-area networks (LANs). MPEG addresses the compression of video signals at about 1.5 Mb/s and of ■ digital audio signal at the rates of 64, 128, and 192 kb/s per channel. It also deals with the synchronization and multiplexing of multiple compressed audio and video bit streams.

> A universal header/ descriptor would make any video stream recognizable by any device

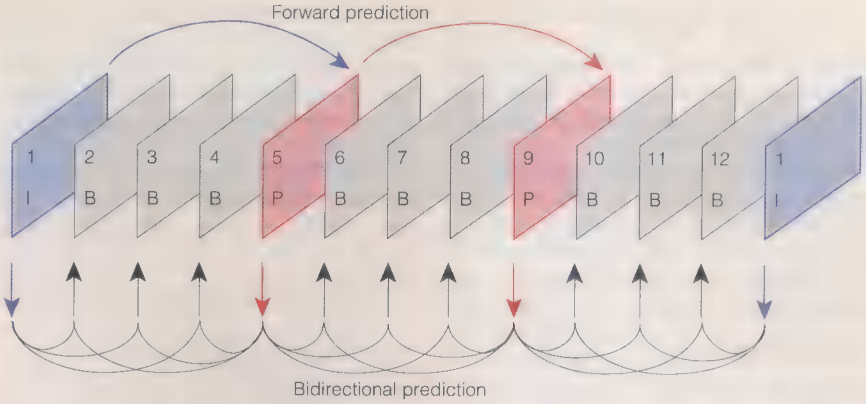
The MPEG standard is generic, that is, it is independent of any one application, said Didier Le Gall, director of research at C-Cube Microsystems, San Jose, Calif., at the Third Annual Electronic Industries Association Digital Video Workshop. The meeting was held in Arlington, Va., in October by the Electronic Industries Association, Washington, D.C., with the participation of the IEEE's Consumer Electronics Society.

To reduce temporal redundancy, Le Gall said, the standard relies on block-based motion compensation, while to reduce spatial redundancy, it relies on transform-based compression. Motion compensation is based on both pure predictive and interpolative codings. Motion information is based on 16-by-16 blocks, is compressed by using variable-length codes for maximum efficiency, and is transmitted along with the spatial information. The variable-length coding takes advantage of the strong spatial redundancy of the motion vector field and is applied to further compress the results of the discrete cosine transform (DCT) and to reduce the impact of the motion information on the total bit rate. Only those codes with ■ fairly high probability of occurrence are coded with ■ variable-length code.

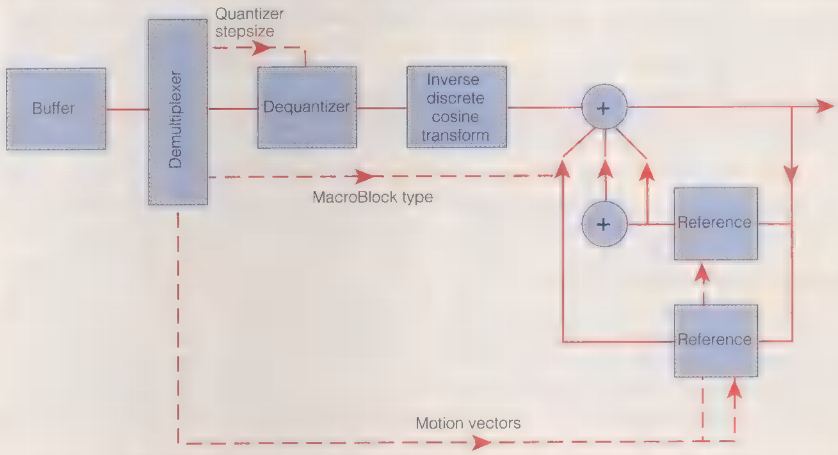
Since the DCT decorrelates the data, its output after quantization is likely to have long runs of zeros. These can be efficiently encoded by a run-length encoder, which simply gives the number of consecutive zeros before a non-zero number. Run-length coding gives a significant degree of compression.

Le Gall said that three types of pictures are considered in MPEG: intrapictures (I frames) that provide access points for random access with moderate compression; predicted pictures (P frames) that are coded with reference to a past picture and are used as a reference for future predicted pictures; and interpolated or bidirectional pictures (B frames) that require both a past and ■ future reference for prediction. Clearly the three picture types are related [Fig. 1].

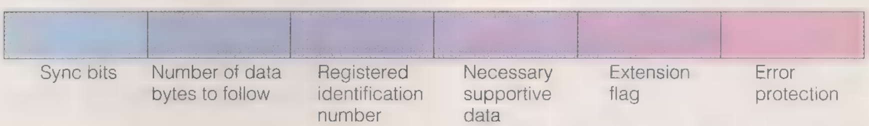
MPEG exploits the temporal redundancy of video signals through motion-compensated prediction. The assumption here is that the blocks of the current picture can be modeled as ■ translation of blocks of some previous picture. Also used is motion-compensated interpolation, which adds a



[1] Display order for frame groups for MPEG—one of three main digital video standards—consists of interframe coding based on intrapictures (I), predicted pictures (P), and interpolated, bidirectional prediction (B). Here an intrapicture is inserted after every 11 frames and the ratio of interpolated pictures to intra- or predicted pictures is three to one. Organization of the pictures is flexible and depends upon such parameters as coding delay.



[2] A typical MPEG decoder would contain a receiving buffer for the coded bit stream used to verify that an MPEG bit stream is decodable with a reasonable buffering and delay requirement. The bit stream is demultiplexed into overhead information (motion information, quantizer stepsize, macroblock type, and quantized digital cosine transform, or DCT, coefficients). The DCT coefficients are dequantized and fed to an inverse DCT unit. A reconstructed waveform from the IDCT is added to the result of the prediction. Two reference pictures are used to form the predictor.



[3] A basic header/descriptor system for enabling recognition of a digital video signal consists of header identification and length, service identification, any supporting data needed, an extension flag to indicate if additional blocks of data should be accessed, and error protection.

correction term to a combination of a past and future picture reference. Motion-compensated interpolation makes possible a high degree of compression.

To reduce spatial redundancy, MPEG uses DCT coding, as in JPEG and H.261. DCT transforms a block of pixel intensities into a block of frequency transform coefficients. The transform is applied in turn to new blocks until the entire image has been transformed. At the decoder in the receiver, the inverse transformation is applied to recover the original image.

MPEG also uses visually weighted quantization—that is, coarser quantizers can be used for the higher frequencies because subjective perception of quantization error varies greatly with frequency. Acording to Le Gall, the exact quantization matrix used depends on parameters such as the characteristics of the intended display, the viewing distance, and the amount of noise in the source.

The MPEG standard specifies a layered structure, syntax, and bit stream for video on digital storage media. The layered structure separates entities in the bit stream that are logically distinct. The syntax provides for application-specific features without penalizing applications that do not need those features.

An example of bit-stream customization given by Le Gall involved providing random access to, and the ability to edit, video stored on a computer hard disk. He explained that such operations would require many access points. Groups of pictures would be coded with a fixed number of bits to make editing possible.

The MPEG syntax contains six layers, each of which supports functions such as DCT, motion compensation, resynchronization, and random access point. The syntax also defines the bit stream, which is characterized by two fields: bit rate and buffer size. The latter specifies the minimum buffer size necessary to decode the bit stream within the context of the video buffer verifier. It is an abstract model of decoding used to verify that an MPEG bit stream can be decoded with reasonable buffering and delay requirements.

Le Gall explained that encoders and decoders are not specified *per se* in the proposed MPEG standard. In other words, an encoder is an MPEG encoder if it can produce a legal MPEG bit stream, and a decoder is an MPEG decoder if it decodes an MPEG bit stream satisfactorily [Fig. 2]. The standard defines only the bit-stream syntax and the decoding process. This allows for enhancements in encoder performance as technology advances.

A new phase of MPEG committee activities is addressing the need for a video compression algorithm for higher-resolution signals at bit rates up to 10 Mb/s.

OTHER VIDEO FORMATS. In addition to JPEG, H.261, and MPEG, a number of video formats must be taken into account when considering the problem of system interoperability. They include the analog television formats of NTSC, PAL (phase alternating line), and Secam (sequential color and memory), the digital formats of proposed HDTV broadcast systems for the United States, and proprietary multimedia digital video formats. The last-named include Digital Video Interactive (DVI) from Intel, Compact Disc Interactive (CD-I) from Philips Consumer Electronics, CDTV from Commodore Electronics, and PhotoCD from Kodak.

For the family of multimedia products coming on the market, the Interactive Multimedia Association (IMA), based in Washington, D.C., has been active in promoting industrywide compatibility. In the fall of 1988, it formed the IMA Compatibility Committee to develop recommendations for multimedia applications that would permit their portability across a variety of hardware-software platforms. The committee has focused first on interactive video applications in the MS-DOS environment, but plans later to study other operating systems and multimedia technologies.

A first draft of recommended practices was produced in August 1989 and a revised draft in February 1990. The final document, "Recommended Practices for Multimedia Portability," Release R 1.1, was published in October 1990. Among its recommendations are commands for general system services, visual management, videodisc players, and X-Y-input devices. The recommended practices furnish platform independence but not device interoperability (plug-and-play). (Device interoperability requires classes of related devices to furnish functionally identical services at the component level.)

Platform independence lets applications run unchanged on any platform based on the same general class of host computers. They can do so only if the different hardware and software platforms show consistent behavior at the application-interface level. Furnishing that consistency is the goal of the interface and command definitions.

In November 1990, the U.S. Department of Defense (DOD), Washington, D.C., incorporated the IMA specification in Military Standard 1379 Appendix D. On March 14 last year, the DOD issued an instruction (1322.20) entitled "Development and Management of Interactive Courseware." That instruction mandates that all interactive multimedia courseware and hardware systems purchased by the DOD must comply with the IMA specifications. And the IMA has coordinated its compatibility efforts with the National Institute of Standards and Technology (NIST), Gaithersburg, Md.

The efforts being put into standards like JPEG, H.261, and MPEG, and the work on multimedia platform interoperability go far to make digital video more generally usable. But before digital video interchange can become widely possible, a standardized header/descriptor and a reference structure for interformat exchange are essential. They would enable the recognition of any video signal so that the receiving device could display it—if that device had the necessary decoding circuits.

> Standards are being developed for coding still pictures, for video conferencing, and for full-motion video

At this writing, the SMPTE draft standards for the two elements were not yet available. But *Spectrum* did talk about them with NBC's Stanley N. Baron. Baron told us that the SMPTE header/descriptor standard would define a single digital transport protocol for all services, each of which would be uniquely identified within the context of the protocol. A key feature of the protocol, he said, is that it permits the bypassing of any data blocks pertaining to services "for which there is no interest, for which access is denied, or which are not defined in the receiver in question."

Baron cited key functions of the header and descriptor. The header would:

- Identify by a registered number the encoded standard used by the attached block of data.
- Specify the length of that block of data so that data could be bypassed as described previously.
- Indicate whether a descriptor—an extension of the header—follows the header.
- Permit users to intercept data streams randomly and identify services quickly.

The descriptor's chief function is to add information to improve the usefulness of the data to the user. It also provides a means of self identification and error protection [Fig. 3].

Baron gave us an example of how the header/descriptor might be used with the proposed digital HDTV transmission systems for a U.S. terrestrial standard. A header identification number could be assigned to the video data blocks, another could describe the type of audio (monophonic, stereo), and a third the program or program source identification (or the program identifier could contain the bits necessary to identify the audio service).

Using this scheme, Baron told us, the entire basic service could be defined in a data service requiring as little as less than 20 bytes of data per video frame, or 4800 kb/s. But by providing for extensions, the system could be expanded to accommodate the service needs of the local community.

SPECIAL REPORT / CONSUMER ELECTRONICS

Putting the standards to work

Personal computers, compact-disc players, and multimedia systems are some of the products using standard video formats

Many of the proposed video format standards are not yet official. All the same, products under development are being based on them—as well as on the formats that have been officially approved.

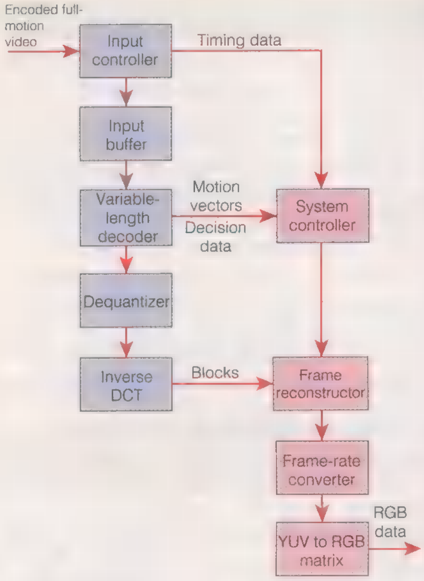
Among the many users of the JPEG standard is NeXT Computer Inc., Redwood City, Calif. NeXTstep, the standard operating environment on NeXT computers, includes support for the JPEG draft in its 2.0 version. All applications that use the NXImage class can read JPEG-compressed tag image file format (TIFF) files. The decompression and imaging of a 24-bit 640-by-480-pixel image takes less than 10 seconds on a NeXT computer equipped with a Motorola 68040 processor.

The i750 video processor, used in the DVI multimedia system from Intel Corp., Princeton, N.J., can process images encoded with the JPEG draft standard. It can decode a 640-by-480 JPEG-encoded image in less than one second. Intel is now developing a chip that will handle MPEG decoding for introduction later this year.

CD-I TO GO MPEG. A good example of the trend to full-motion video in multimedia products is the Philips Imagination Machine, a CD-I home entertainment system that

Some network protocols and their bit-rate regimes

Service	Bit-rate regime
Conventional telephone	0.3–56 kb/s
Fundamental bandwidth unit of telephone company (DS-0)	56 kb/s
Integrated-services digital network (ISDN)	64–144 kb/s
Personal computer local-area network	30 kb/s
T-1 (multiple of DS-0)	1.5 Mb/s
Ethernet (packet-based local-area network	10 Mb/s
T-3 (multiple of DS-0)	45 Mb/s
Fiber-optic ring-based network	100–200 Mb/s



[4] Philips Research Laboratories designed this Compact Disc Interactive (CD-I) decoder for full-motion video. Once the video is decoded from luminance and chrominance (YUV) data and converted to red-green-blue (RGB) data, it can be shown as a partial-screen display together with other video partial-screen displays.

combines CD-quality audio with video, text, graphics, animation, and interactive capabilities. The product debuted in New York City on Oct. 16. The CD player is connected to any TV receiver and stereo system. A standard 5-inch CD-I disc is loaded in the same way as a CD-Audio disc and is controlled by a remote control thumbstick.

Users direct the action on the TV screen, activating selected areas by pointing to and clicking on command areas on the screen (noted with symbols or words). The user may also interrupt a program while it is running, whether to recall a certain choice, go back to a previous step, ask for more detailed information, or request information in another language.

The Magnavox CDI910 player was developed to a worldwide CD-I standard to ensure compatibility with all CD-I discs developed, regardless of make, manufacturer, or country of origin. The player will also play 3-inch and 5-inch CD-Digital Audio discs, CD+Graphics discs and visuals, CD ROM-XA "bridge" discs, and Photo CD discs.

The current player has still picture and animated video capabilities but not full-motion video. But an MPEG-based full-motion video module will be available from Philips later this year and will plug into a socket already in place on the back of the CD-I player chassis.

An input controller in the decoder [Fig. 4] receives the encoded full-motion video bit stream and stores it in a buffer. The controller also extracts timing data—used to synchronize video with other functions, such as audio, and to ensure that real-time demands from the bit stream are obeyed—and sends that data to the system controller. The output from the buffer is processed by a variable-length decoder, which recovers motion vectors, decision data, and quantized blocks from the encoded bit stream and passes them to the system controller. The quantized blocks are also dequantized and transformed by an inverse discrete cosine transform.

The 8-by-8 luminance or chrominance blocks that are the transform's output go to a frame reconstructor, which processes them, together with the motion vectors and decision data, to reproduce the frames. Reconstructed frames are available with a frame rate of 24, 25, or 30 Hz. The rate depends on the frequency of the coded video after subsampling. The YUV representation of the frames—the specific representation of luminance and chrominance used in the encoder and decoder—is transformed to an RGB representation, which can then be displayed on a portion of the screen.

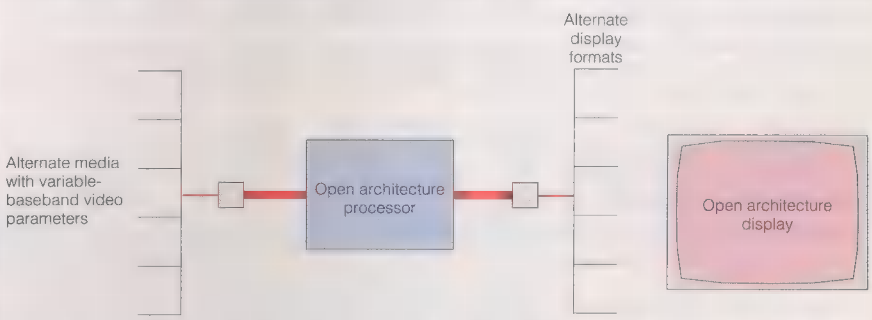
Last April Philips Consumer Electronics Co., Knoxville, Tenn., and Motorola Inc., Schaumburg, Ill., announced plans to cooperate in developing chips for CD-I and MPEG. Philips subsequently announced its cooperation with C-Cube Microsystems Inc. to develop real-time compression chips.

With full-motion video capability, a CD-I disc could conceivably be used for full-length movies that would be displayed on the full screen. In that event, the CD-I discs would compete with laser discs.

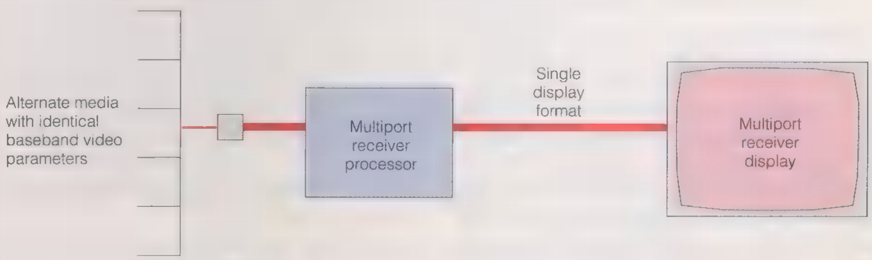
PHOTO CD SYSTEM. Philips has also worked with Eastman Kodak Co., Rochester, N.Y., on new features for the Kodak Photo CD system announced in September 1990. The idea behind the system is to enable consumers to have their 35-mm negatives or slides inexpensively scanned and digitized by photofinishers for storage on Photo CD discs. These discs, which hold up to 100 images of photographic quality, may be loaded on a personal computer with a CD-ROM drive. With Photo CD software, available in the Photo CD Access developer toolkit, the stored images may be modified, manipulated, and exported for use in such applications as word processing, desktop publishing, and painting and drawing packages.

Announced by Kodak and Philips at the Consumer Electronics Show in Las Vegas, Nev., in January was the news that sound, text, and graphics can now be recorded with the photographic images onto the Photo CD discs. The discs with interactive playback capabilities will be playable on TV receivers with dedicated Photo CD players (to be available this summer), on CD-I players, and on computers with CD-ROM XA (extended architecture) drives. Prerecorded discs carry up to 800 images, digitally recorded at TV resolution, or up to 72 minutes of full CD audio sound, or any combination thereof. Disc users will control their viewing of the contents through a simple infrared remote control device. The player also plays standard CD audio discs. A Huffman encoding process was used to obtain lossless compression after quantization of the high-frequency residual images.

MPEG FOR HDTV, TOO. At least one of the proposed U.S. digital HDTV terrestrial transmission formats ["The challenges of digital HDTV," *IEEE Spectrum*, April 1991, pp. 28–30, 71–73] uses a video compression technique based on MPEG. The Advanced Digital Television (ADTV) entry from the

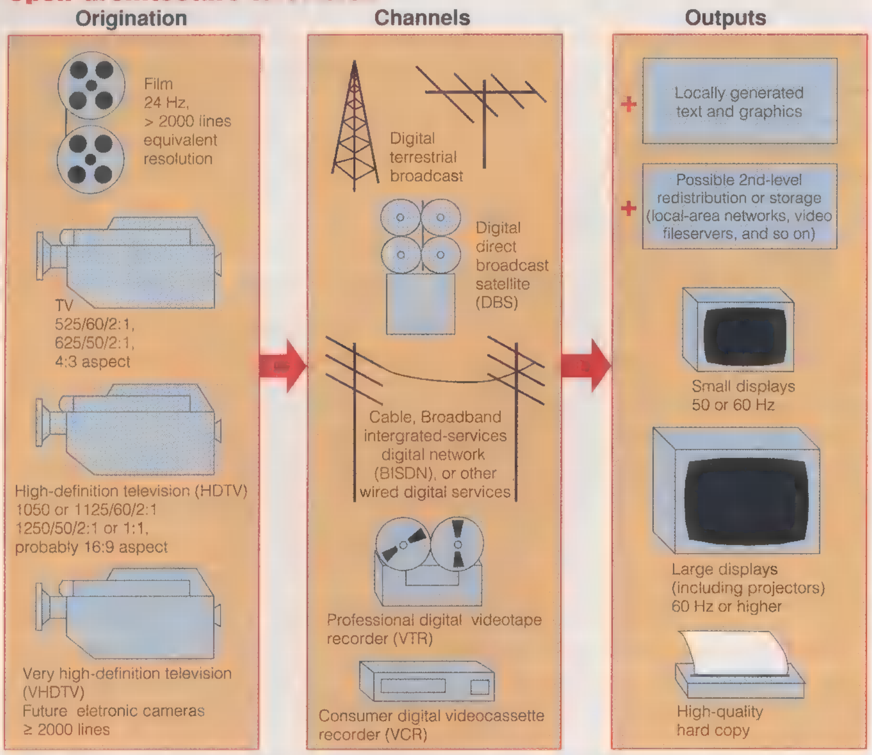


[5] An open-architecture receiver can handle media employing variable-baseband video parameters and produce displays in a variety of formats.



[6] A multiport receiver handles media with like-baseband video parameters and uses a single display format.

Open-architecture television



[7] An open-architecture TV receiver decouples the numerical parameters of origination, channel, and output of video images.

Advanced Television Research Consortium—NBC, David Sarnoff Research Center, Philips Consumer Electronics, Thomson Consumer Electronics, and Compression Labs Inc.—incorporates MPEG++ that upgrades the MPEG compression approach to HDTV pictures at 20 Mb/s.

OPEN OR MULTIPORT RECEIVERS? Even given a standard header/descriptor to identify an incoming bit stream of coded video data, the receiving device will not be able to display the video unless it can decode that particular bit stream. With the proliferation of video formats, this presents a problem. Whereas it might be relatively easy to design TV receivers that could decode NTSC, PAL, and Secam signals (if costs were no problem), it would be very much more difficult to design a receiver that could decode every video format.

By and large, "all-purpose" receivers could have either an open architecture [Fig 5] or a multiport design [Fig. 6]. Arpad G. Toth, then chief scientist, Philips Laboratories, Briarcliff Manor, N.Y., and now with Eastman Kodak Co., described both at the first Digital Systems Information Exchange meeting in November 1990.

The open-architecture receiver, he said, would support multiformat emission and display parameters. But, he cautioned, although its ability to process and monitor digital multiresolution video could be a potential asset for the workstation and personal computer, it would present a problem for TV receiving systems. They may require simpler and minimum-cost design rules—hence the generation of the multiport receiver concept.

A multiport receiver could be viewed as a special case of an open-architecture receiver, Toth said. "The input and output interfaces of the receiver would allow maximum user flexibility for interconnection without any signal degradation," he explained.

Development of architecture and interface standards for the multiport receiver in both analog and digital video applications, he reported, was well under way within the Electronic Industries Association, Washington, D.C.

The significance of open architecture and scalability was discussed by V. Michael Bove Jr. and Andrew B. Lippman of the Massachusetts Institute of Technology's Media Laboratory, Cambridge, in the January 1992 issue of the *SMPTE Journal*. They said that open architecture hinged on an intermediate representation for video signals, one that "does not have a fixed sampling raster or frame rate, and which can exist at a range of bandwidths."

They described work at the MIT Media Laboratory on applying the open-architecture concept to the entire television system [Fig. 7]. The goals are to maximize the interconnection options and to permit production, distribution, storage, and viewing to employ a variety of standards optimized for specific situations.

An open-architecture video representation is scalable in resolution, they emphasized. In other words, the number of lines on the display is determined strictly by the receiving hardware and is not coupled to the number of lines used by the production equipment. Scalability means that it should not be necessary to decode the entire transmitted signal to obtain an image at lower resolution than the source. The signal is also scalable temporally, they reported, so that the frame rate of production and display are decoupled.

TO PROBE FURTHER. The April 1991 issue of the *Communications of the ACM* is a special issue on digital multimedia systems. It was published by the Association for Computing Machinery, 11 W. 42 St., New York, N.Y. 10036; 212-869-7440. This article draws on some of the material published in that issue.

Descriptions of the JPEG and H.261 coding algorithms are contained in the article, "Video compression makes big gains," by Peng H. Ang, Peter A. Ruetz, and David Auld, in the October 1991 issue of *IEEE Spectrum*, pp. 16–19.

For detailed information on Intel Corp.'s Digital Video Interactive (DVI) technology, see *Digital Video in the PC Environment*, second edition, by Arch C. Luther (McGraw-Hill, New York, 1991) and "Multimedia Applications Development Using DVI Technology," by Mark J. Bunzel and Sandra K. Morris (McGraw-Hill, New York, 1992).

An interim report of the FCC Advisory Committee on Advanced Television Systems recommends that the headers/descriptors notion be adopted by the FCC. For a copy, contact Robert Sanderson, Eastman Kodak Co., Rochester, N.Y.; 716-253-5362.

For an update on multiport receiver developments, contact the Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, D.C. 20006-1813.

The February 1992 issue of the *IEEE Transactions on Consumer Electronics* contains three papers from the Digital Video Workshop held in October. Contact IEEE Publication Sales, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-11331; 908-981-0060.

The Society of Motion Picture and Television Engineers (SMPTE) welcomes the participation of any individual or group that has an interest in the header/descriptor standards work. Contact Sherwin H. Becker, director of engineering, SMPTE, 595 West Hartsdale Ave., White Plains, N.Y. 10607; 914-761-1100.

The January 1992 issue of the *SMPTE Journal*, pp. 2–5, contains an article "Scalable Open-Architecture Television," by V. Michael Bove Jr. and Andrew B. Lippman.

The proceedings of SMPTE's 26th Annual Advanced Television and Electronic Imaging Conference, held in San Francisco, Feb. 7–8, is available from the society. That meeting addressed the serious need for technological compatibility between television and computers.

The Interactive Multimedia Association's "Recommended Practices for Multimedia Portability," Release R 1.1, is available from the organization, 800 K St., N.W., Suite 440, Washington, D.C. 20001; 202-408-1000. ◆

Refreshing curricula

To cut down on dropouts, U.S. engineering schools are devising lively courses that emphasize hands-on design and teamwork

Graduates of U.S. high schools who go on to college are choosing engineering schools in dwindling numbers. Last year, for example, there were 19 percent fewer engineering bachelor's degrees awarded than in the peak year of 1986, according to the American Association of Engineering Societies, Washington, D.C.

Worse, many of those who do enroll in engineering drop out after a year or two, disappointed and bored with courses that seem to have little relevance to the workplace or to society. Women, blacks, Hispanics, and American Indians—already underrepresented in the student body—leave engineering schools in disproportionately large numbers. For example, Cornell University, Ithaca, N.Y., which prides itself on the relatively large number of women entering its engineering program (more than 30 percent this year), has nevertheless found that an average of 39 percent of women drop out of engineering compared to 27 percent of white men.

At the same time, employers of recent engineering graduates complain that many new engineers are poorly prepared for the realities of the twenty-first century. Graduates may be well-trained in engineering analysis, employers say, but they lack skills in interdisciplinary problem-solving, concurrent engineering, teamwork, and communication—all vital for today's intensely competitive industries.

Not surprisingly, these problems have prompted movements aimed at reforming engineering school curricula. One of the most prominent is the Synthesis Coalition, a five-year, US $15.3 million project begun in Sept. 1990 by the National Science Foundation (NSF), Washington, D.C., and eight member institutions. Participating are California Polytechnic State University, San Luis Obispo; Cornell; Hampton University, Virginia; Iowa State University, Ames; Stanford University, California; Southern University, Baton Rouge, La.; Tuskegee University, Alabama; and the University of California, Berkeley.

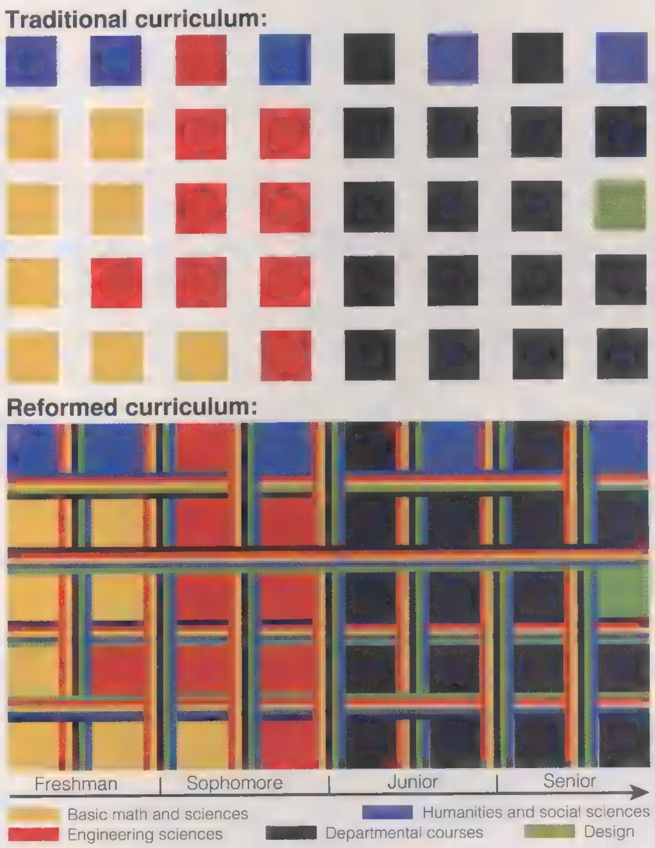
"The term *synthesis* means integration of engineering knowledge, including design, in union with broad societal concerns," Robert J. Thomas told *IEEE Spectrum*. Thomas is a professor of electrical engineering at Cornell and chairs the technical communications subcommittee of the Synthesis Coalition. "The integration is both horizontal—that is, interdisciplinary—and vertical—uniting precollege through post-grad education," he commented.

Industry plays a big role in the Synthesis Coalition, too. Some 20 companies in such fields as publishing, computers, and telecommunications advise Thomas's subcommittee on software and hardware standards for classrooms, courseware development studios, and databases. In addition, companies provide equipment, technical support, and funding for many coalition projects.

The Synthesis Coalition is not the only reform movement, to be sure. Many engineering colleges across the United States have instituted their own curriculum innovation programs. For example, the Department of Electrical and Computer Engineering at Carnegie Mellon University, Pittsburgh, recently proposed a radically new undergraduate curriculum in which freshmen learn circuit and logic concepts and build a working robot. And the NSF is funding a parallel effort, the seven-university Engineering Coalition of Schools for Excellence in Education and Leadership (Ecsel), a group that stresses the teaching of leadership and management skills. Seniors from a variety of engineering disciplines will work together on design project teams.

Interestingly, little curriculum reform seems to be going on outside North America, according to several U.S. engineering educators. For example, Wolfgang Sachse, a professor of theoretical and applied mechanics at Cornell, recently visited universities in France and Germany and found that course development there proceeded along traditional lines, though European engineering educators followed U.S. innovation efforts with much interest.

INTERWEAVING. Synthesis Coalition members view the traditional undergraduate curriculum as a rigid sequence of courses that are narrowly focused and compartmentalized. Early courses, they say, tend to be abstract and seem unrelated to the practice of engineering; students are asked to accept on faith that they are truly important to their careers. And design courses are not introduced until late in the program, at which time they may come as a shock to many students.



Many educators regard the traditional undergraduate engineering curriculum as fragmented. The Synthesis Coalition plans to change that by interweaving minicourses in the basics, in engineering, in the humanities, and in design throughout a student's academic years.

George F. Watson Senior Editor

0018-9235/92/$3.00©1992 IEEE

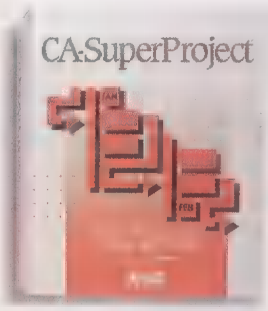
Introducing Po
For Project

The #1 Rated Project Manager Now Available For Windows.

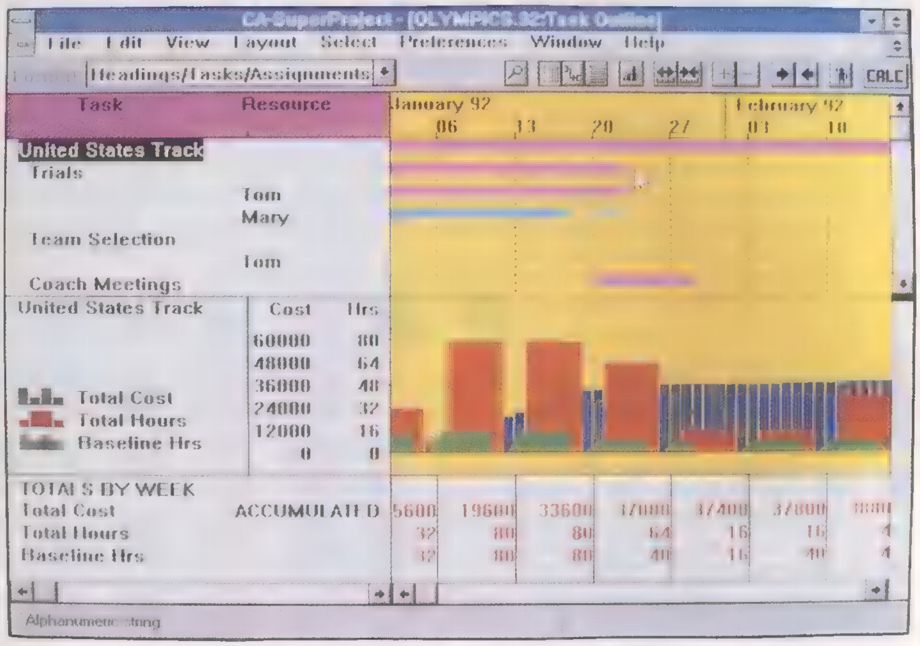
Power changes people.

Especially project managers.

They work smarter and faster with new CA-SuperProject™ For Windows. It's always been the world's most advanced, efficient and reliable project management software.



And now that it's Windows compatible, it's also the easiest to use.



New CA-SuperProject For Windows gives you all the power you'll need for any project with tools for sophisticated planning, comprehensive resource management and powerful tracking and controlling.

Total power is yours with a few mouse clicks. Graphically create and edit projects. Specify resources, task types and durations. Define integrated sub-projects. Build top-down hierarchies and task-dependency relations. Link multiple projects together for cross-project leveling.

Create, edit, view– total power over any project is yours with just a few mouse clicks.

Perform extensive "what-if" analysis, revising schedules as projects progress.

You can bet your career on its advanced algorithms, which calculate the most efficient project schedules in the industry.

MICROSOFT® WINDOWS™

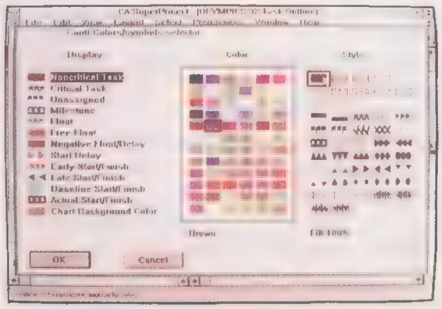
ower Windows Managers.

A recent study of the five leading project managers proved it. Each was assigned the same project, but the completion dates varied by as much as five months.

CA-SuperProject For Windows finished first in 214 working days—leaving Microsoft Project, Timeline 4.0, Project Workbench and Project Scheduler in the dust.

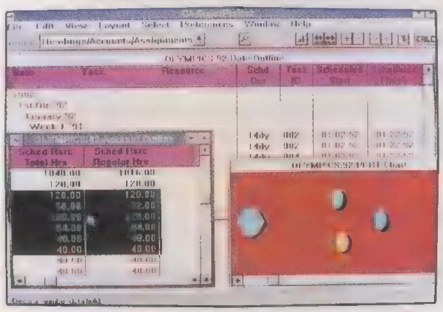
Vibrant, state-of-the-art graphics and detailed reporting tools help bring your projects to life.

You can choose from WYSIWYG fonts, symbols, colors and shade patterns to highlight your Gantt,PERT, WBS and Cost/Resource charts.



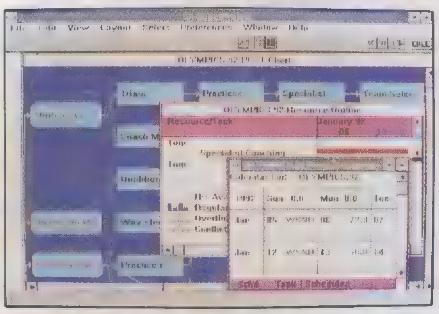
Bring projects to life with a full array of WYSIWYG on-screen interactive graphics, colors, fonts, symbols and shade patterns.

Start by specifying resources, task types and task durations—all in a matter of seconds.



Perform extensive "what-if" analysis, revising schedules as your projects progress.

Show multiple views of the same project or different projects simultaneously.



Report the status of your project with detailed Gantt, PERT, WBS and Cost/Resource charts.

For your free Demo Disk, call 1-800-CALL CAI.

Call today.

And find out what our power windows can do for you.

COMPUTER® ASSOCIATES
Software superior by design.

CA-SuperProject® For Windows

Circle No. 11

Attempting to change that conventional order, the coalition is introducing design projects at the outset and weaving math, basic science, engineering science, multidisciplinary, and humanities courses throughout the four-year program [see figure].

In all, the coalition has some 70 projects in various stages of preparation. Several of them are aimed at attracting a steady supply of qualified degree candidates—filling the pipeline, in coalition parlance—by reaching out to precollege students. Other modules are aimed at teaching teachers—preparing them for reformed curricula and high-tech classrooms.

Still others cover traditional engineering subjects that are transformed according to Synthesis Coalition tenets. For example, Logic Synthesis teaches logic system design and rapid prototyping principles and techniques. Electric Power Systems Synthesis teaches difficult concepts in analysis and design of power networks with the aid of visualization and simulation software and hardware.

MULTIMEDIA CASE STUDIES. To promote horizontal integration, the coalition is developing a variety of course modules. An example is Multidisciplinary Multimedia Case Studies in Engineering Design, which combines the case study method with computers and hypermedia. Instead of poring over hard copies of figures, specifications, graphs, and reports, students will navigate at their own speed, using video displays, through databases to learn how products were conceived, what design decisions were made and why, what the stages of design and development were, and how the products were designed for easy assembly and manufacture. The students are also able to examine issues of reliability, maintenance, social implications, and marketing. The course will be offered from freshman to senior years.

"Instructors benefit, too," said Alice Agogino, an associate professor of mechanical engineering at Berkeley and associate director of curricular reform for the coalition. "Each can refer to one aspect of a case study to illustrate a particular engineering principle." Among the products to be studied are an Apple personal computer, a Digital Equipment mouse, an IBM printer, General Electric consumer products, and a Sony compact-disc player. The manufacturers are supplying the information for the database.

> Women, blacks, Hispanics, and American Indians, already underrepresented, leave U.S. engineering schools in excessive numbers

So far, a case study of a human-powered vehicle has been completed and one on the IBM Proprinter is expected to be ready in May, Agogino, who is lead investigator for the module, told *Spectrum*. By next January, results of the module's use in classes at Berkeley, Cornell, Hampton, Iowa State, Stanford, and Tuskegee will be reviewed. Eventually the courseware will be made available to schools that do not belong to the coalition.

Meanwhile, Agogino is supporting vertical integration by developing versions of the case study course for precollege outreach programs for women and minorities. In this guise, it is expected to stimulate interest in engineering as a career and prepare prospective students by acquainting them with engineering concepts and methods.

Another interdisciplinary course is Mechatronics, for which David Auslander, another associate professor of mechanical engineering at Berkeley, is lead investigator. In it, students learn how to integrate mechanical equipment and embedded microprocessors by writing control software, designing mechanical hardware, and evaluating their creations.

Southern University just implemented the course this winter semester, and Cal Poly plans to do so when its spring semester begins this month. Tuskegee and Hampton plan to follow suit. "We don't have any measured results yet, but the kids seem to like it a lot," Auslander told us.

A course aimed at stemming the loss of first-year students is Freshman Engineering, whose development is being led by Robert Heidersbach, head of the materials engineering department at Cal Poly. Although the course is likely to take many forms, depending on local needs, it is essentially a series of minicourses in which faculty make presentations, with visuals and demonstrations, on topics of current interest.

Students get practice in writing and speaking, gain hands-on experience with workstations, read and discuss topics like design techniques and engineering ethics, and learn basic survival skills such as how to function in a bureaucracy and how to deal effectively with faculty members.

"The majority of engineering students who leave engineering do it during or just after the freshman year," Heidersbach observed. "This course could stem this leak in the pipeline."

The course was first offered last fall at Cal Poly and Southern. Charles Burris of Southern's mechanical engineering department has injected design into his version of the course. He believes that, with professional coaching, beginners can learn design methodologies even though they may lack background in engineering fundamentals. "Freshmen are assigned a simple but practical design project—one is a paint-can holding fixture—and required to come up with drawings and a report," Burris said. The professor compares the progress of students in the pilot section with that of students in traditional sections.

Yet another effort to stem leaks is Spatial Reasoning, for which Berkeley's Agogino is co-lead investigator with Marcia Linn, director of the Instructional Technology Program in Berkeley's department of education. The module, involving both research and course development, is based on the hypothesis that spatial reasoning—the ability to visual-

Engineering super Nova

Anthony R. Ingraffea

Education is impossible without manipulating information. Creating, transmitting, storing, cataloging, retrieving, displaying, and interacting with information—all this is the business of education. Insight, imagination, creativity, and passion are its soul. It always surprises me, then, that I often have to explain and justify a massive infusion of new information technology to engineering professors.

Such new technology is now being developed through the Synthesis Coalition, a five-year project by the National Science Foundation and eight member universities aimed at reforming engineering school curricula. We in the coalition are not telling engineering educators that chalk and blackboards must be destroyed; these tools will continue to be part of teaching for the foreseeable future.

Rather, we are saying, "Stop thinking of computers as only computers!" They are systems that can handle all of the business of education as well as enhance its soul.

In a classroom or lab, computers can slow down things that are too fast to see (like wave propagation) or speed up things whose motion is too slow to be discernible (like plate tectonics). And they can enlarge things that are so small as to be almost invisible (like integrated circuit junctions). Even the most dedicated professor could never do this with blackboard and chalk.

I was criticized recently for "just trying to make 'Nova' PBS [Public Broadcasting System] segments out of engineering education." Actually, to many students that would be a great idea, but we are going a few steps further than "Nova." A "Nova" program is serial, noninteractive, and not conducive to close faculty-student and student-student interaction. Moreover, it is generally too big a bite of information to please any professor completely.

What we have in mind is similar in technology—graphics, sound, video, the sense of being there—but with solid pedagogy appropriate to the classroom and laboratory, not the family room, so we don't restrict free expression of the soul.

Anthony R. Ingraffea is director of the Synthesis Coalition and a professor of civil engineering at Cornell University, Ithaca, N.Y.

ize three-dimensional relationships—can be improved by interactive courseware to build intuition and successful reasoning strategies.

3-D VIEWS. "Spatial reasoning tasks are part of both engineering courses and engineering practice," Agogino said. "But students who feel inadequate in spatial reasoning may be discouraged from continuing their training or starting it in the first place."

Agogino and Linn are testing tutorial spatial reasoning courseware at Berkeley, Iowa State, and Hampton. In a typical learning session, a student is shown a 3-D view of an object on a workstation and is then asked to construct top, side, and front views by rotating the isometric views. "If we identify learning style differences by gender, ethnicity, or race, we will modify the tutorials for these populations," Agogino said.

Adebisi O. Oladipupo, assistant professor of electrical engineering at Hampton, described how the courseware is used there. In their first weeks, freshmen sketch 3-D objects on paper, then construct folded cardboard models of the objects. After moving on to drawing isometric views from orthographic views, they finally use a workstation and SilverScreen graphics software to construct and manipulate images of objects.

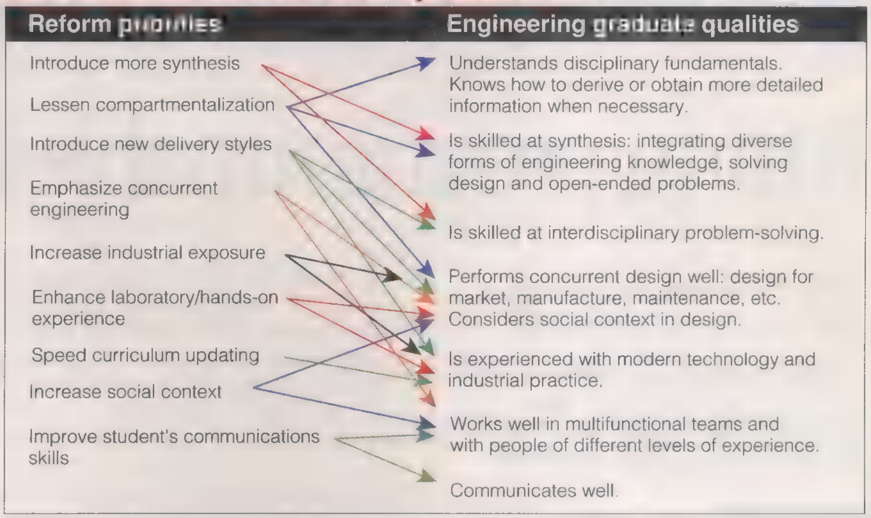
"We're not teaching drafting principles, but how to visualize in the mind's eye," Oladipupo said. "The manual methods—sketching and cutting and folding—are hard but rewarding for students. Then, when they go to software, they find it's easy—and fun!" The spatial reasoning courseware will be released to other schools in the coalition next summer.

Implicit in all this ambitious course development is a high-technology delivery medium, and the Synthesis Coalition is addressing this need through its National Educational Delivery System (Needs) program. Two innovative classrooms went into service on Jan. 20 at Iowa State, according to Arvid R. Eide, associate dean for instruction and student affairs at Iowa State's College of Engineering and the coalition's associate director for supporting technologies.

In those classrooms, instructors have at their fingertips video disc players, videocassette recorders, slide projectors, personal computers, and high-performance graphics workstations with high-resolution color back-projection displays. The instructor can call up courseware elements to illustrate concepts as a planned part of a lecture or to answer spur-of-the-moment questions. Programs can be delivered by satellite downlink, and eventually the classrooms will have satellite uplinks and optical-fiber connections as well.

"We're working, for example, with IBM and Intel on DVI [digital video-interactive] technology, and we're using laser disks, CD ROMs [compact disc–read-only memories], and a lot of multimedia techniques," Eide said. By 1994, all coalition schools—and perhaps a few outside the coalition—will have high-tech classrooms.

How curriculum reform will help students



For its part, Iowa State hopes to construct a new $50 million building containing 15 high-tech classrooms. There, interdisciplinary design and development work will be encouraged. Students will be able to communicate via computer and to examine collective projects and make changes in them, as in concurrent engineering.

PORTABLE DISPLAYS. The Synthesis Coalition is well aware of the need to keep hardware costs low so that schools can take advantage of curriculum reform in an era of shrinking budgets. Toward this end, the coalition hopes to design a relatively low-cost portable unit, including a computer and projection system. "There are some nice liquid-crystal displays now that will project full-motion video," Eide told us. "I would say that for about $20 000, we could build a unit that a faculty member could roll into a classroom whenever it's needed."

Classrooms are only part of the Needs program. Eide and co-workers at Synthesis Coalition schools are building a technology database that will be accessible nationwide via high-speed computer networks. Instructors and students will be able to tap the database for courseware, full-motion videos, computer simulations, and mathematical models. Eventually the database will be available to kindergarten through 12th-grade science teachers and community college instructors. (The Synthesis Coalition has already begun to work with community colleges, which are a fertile source of engineering students. It sponsors four-day meetings that bring together community college instructors, counselors, and administrators; representatives of government funding agencies; and educators from engineering schools.)

ASSEMBLING LESSONS. Iowa State's Eide envisions a Needs courseware matrix that relates concepts (mathematics, mechanics, thermoscience), disciplines (aerospace, civil, electrical), and categories (analysis, design, experimentation). The matrix elements will be jointly developed educational segments, 2 to 10 minutes long, stored in a national database. An instructor will assemble a lesson by mixing and matching these segments and supplementing them with locally developed segments dealing with motivation, historical background, or special-purpose experiments and computations.

Each school will have its own courseware development studio where instructors can get help in creating their own courseware segments and integrate multimedia presentations. With only a little technical training, they will be able to combine graphics, sound, video, text, calculations, and simulations.

Convincing teachers of the advantages of the high-tech classroom is a vital part of the Synthesis Coalition's work. "We plan to methodically show faculty how easily they can modify a class or a series of lectures," Eide said. He does not expect total acceptance. "I think there will be those faculty members who think the money would be better spent in their individual research areas. And there will be faculty who will continue to use the blackboard and chalk."

Nevertheless, he predicts eventual conversion. "As a portion of the faculty becomes sold on new teaching methods, their enthusiasm will spread," he said. "Slowly but surely, curriculum reform and the high-tech classroom will take root."

TO PROBE FURTHER. *ASEE Prism*, a monthly magazine, frequently publishes articles on innovative curricula. Contact the American Society for Engineering Education, 11 Dupont Circle, Suite 200, Washington, D.C. 20036; 202-293-7080. The society's 1992 conference will be held June 21–25 in Toledo, Ohio. This year's theme: "Creativity—Educating World-Class Engineers."

The Synthesis Coalition, 445 Engineering and Theory Center, Cornell University, Ithaca, N.Y. 14853, publishes a newsletter, *Synergy*, and a Project Information Guide that provides background on the coalition and summarizes its 1991–92 activities; 607-255-3697; fax, 607-254-8888; e-mail, TAVX@cornellc.cit.cornell.edu. ◆

Fitting programmable logic

New synthesis software for user-programmable logic relieves designers of complex design fitting, placement, and routing

The latest wave of field-programmable gate arrays (FPGAs) and complex programmable logic devices (PLDs) brings system designers two boons: capabilities till now unique to gate array devices and design benefits till now found only in the programmable-array logic (PAL) type of device. But the architectures of the latest devices are many and varied. Each type of user-programmable device has unique traits, some obvious, some obscure. To benefit fully from the new devices, a system designer needs a synthesis software tool that addresses all their idiosyncracies.

The tool is a program called a device fitter. It manipulates a designer's generic logic description until the best possible fit with a particular PLD or FPGA is obtained. As the key to the efficient, optimal utilization of modern programmable logic devices, it is fast becoming a standard item in the designer's electronic design automation (EDA) toolbox.

Device fitting follows functional simulation and generic optimization [Fig.1]. Thus the fitter's input might be a set of sum-of-products equations generated by a design-entry tool, such as schematic-capture or behavioral description software.

The device fitter is far more sophisticated than past gate array or PLD synthesis tools. In most cases, the process is fully automated: the design is entered, the fitter is invoked, and a Jedec-standard-No.3 file or vendor-specific netlist is produced. A fitter thus frees engineers from worry about details, letting them concentrate instead on the architectural consequences and tradeoffs of a design.

Fitters also take on the exhaustive search for the best solutions, which is crucial when the possibilities are as vast as they are here.

The first PLDs appeared in the late 1970s and were based on a simple sum-of-products architecture. They were mainly used to replace the many discrete transistor-transistor logic (TTL) devices needed to make standard large- and/or very large-scale ICs work together, the so-called glue logic. These early PLDs were easy to design with, so systems engineers would often do the fitting manually. Design software of the day supported basic fitting functions; it included Palasm from Monolithic Memories Inc. (now merged with AMD Inc., Santa Clara, Calif.) and early versions of ABEL from Data I/O Corp., Redmond, Wash.

Thomas R. Clark Data I/O Corp.

The new programmable logic is quite different. Recent PLDs and FPGAs have three or more logic levels, whereas the original devices only had two. New devices may consist of two or more programmable arrays versus the single-array PLDs of yore. Complex PLDs and FPGAs generally have programmable routing, simple devices do not.

FPGAs. The new devices split broadly into two groups: FPGAs and complex PLDs with multiple partitions.

A basic FPGA design issue is that each device has a different level of granularity—that is, the size of their fundamental electronic structures varies. Some chips have large logic structures; the Logic Cell Array (LCA) from Xilinx Inc., San Jose, Calif., consists of input/output blocks (IOBs) surrounding configurable-logic blocks (CLBs), with each CLB including registers as well as combinational logic [Fig. 2]. Others resemble conventional gate arrays in their granularity; the ACT 1 FPGA from Actel Corp., Sunnyvale, Calif., comprises a matrix of logic modules, with the rows separated by wiring channels.

> The logic-fitting process is usually automated: the design is entered, the fitter invoked, and the netlist produced

The large-grain registers of the LCA let the designer compactly implement register-intensive designs that would require large amounts of fine-grain random logic. On the other hand, when large combinational circuits are required (particularly if they have large fan-in requirements), complex logic blocks can be wasted on simple gate functions. For large combinational circuits, devices such as Actel's with flexible, fine-grain logic blocks give higher device utilization. Although circuits implemented in an Actel FPGA can be faster than the same circuit implemented in an LCA, the timing characteristics of both are routing-dependent.

Unlike the LCA and the Actel FPGA, the Hiper 2020's timing characteristics are not affected by the routing process, and architecturally it has characteristics of both an FPGA and a PLD. A universal interconnect matrix (UIM) interconnects the eight functional blocks in this multilevel-architecture device from Plus Logic (which was recently acquired by Xilinx). Each functional block is a fully programmable AND array that generates 57 intermediate product terms. There are 21 inputs from the UIM as well as nine output cells for each functional block, and each cell has a logic expander, which is similar to a PLD's product-term–steering block.

PLDs. The newer PLDs have multiple-partitioned architectures, with each partition in effect equalling earlier PLDs in complexity, and may be using hard-wired buses or fuses for interconnection.

A good example of this architectural type is the MACH210, a member of one of the most popular families—AMD's MACH (Macro Array CMOS High-density) electrically erasable PLDs. It consists of four programmable-array logic (PAL) blocks interconnected by a programmable switch matrix [Fig. 3]. Each PAL block includes a 64-term sum-of-products array, plus I/O macrocells and buried registers. The switch matrix feeds each PAL block with 22 inputs. The PAL blocks, in turn, provide the switch matrix with 16 internal and eight I/O feedback signals, for distribution to the PAL blocks.

Along with partitioning come product-term–steering architectures, special ways of assigning product terms to a block. By steering additional product-term inputs to the appropriate macrocell, designers can implement equations with many OR terms as two-level logic. Among the widely used techniques are allocation, joining, and expander logic.

In allocation, the number of product-term inputs to a macrocell is increased by taking logic from a neighboring macrocell. An example of the allocation architecture is the

0018-9235/92/$3.00©1992 IEEE

5AC312 from Intel Corp., Santa Clara, Calif., whose 12 macrocells each have two groups of four product terms. Each macrocell can surrender one group to each adjacent macrocell; alternatively, it can take a group from each adjacent macrocell. For instance, if macrocells A and C require 12 product terms apiece for their equations, they can each take a group from B. So doing would, of course, leave B without product terms and therefore unusable. In most cases, however, equations can be placed in a way that leaves each macrocell with at least four terms.

In joining, product-term inputs are increased by sharing inputs. In the 2500 from Atmel Corp., San Jose, Calif., for instance, each macrocell contains 12 product terms, evenly divided among the macrocell's combinational logic block and two buried registers. Product-term inputs to the combinational logic can be increased by being "joined" by the buried register product terms; all 12 inputs can be used combinationally if required. Yet, while additional product terms are joined to the combinational-logic output, they remain available to the buried registers.

From the device designer's viewpoint, joining and allocation reduce the total number of product terms required per block and hence the number of actual gates. Since most circuits that will be implemented in a PLD require rather few product terms (four, say) for most outputs, the goal of the PLD designers has been to reduce the total number without restricting applications that require a lot more (16, say) for certain logic functions. Joining and allocation allow the number of product terms per output to be adjusted to a design's needs, and do so without affecting the timing characteristics of the final circuit.

A disadvantage of these approaches is that output signals must be allocated to device pins on the basis of their product-term requirements. This can make fitter software more complex and costly to develop; it must be careful not to group together outputs with large term requirements, since each output may borrow product terms only from an adjacent macrocell.

In the expander approach, seen in the MAX EPM5128 from Altera Corp., San Jose, Calif., a separate array provides a pool of expander terms from which the user can draw to add to the normally allocated output terms. This flexibility lets the designer place much larger logic functions (16 or more) on a given output than other term-sharing architectures. However, there is a small timing penalty, and possible output skew.

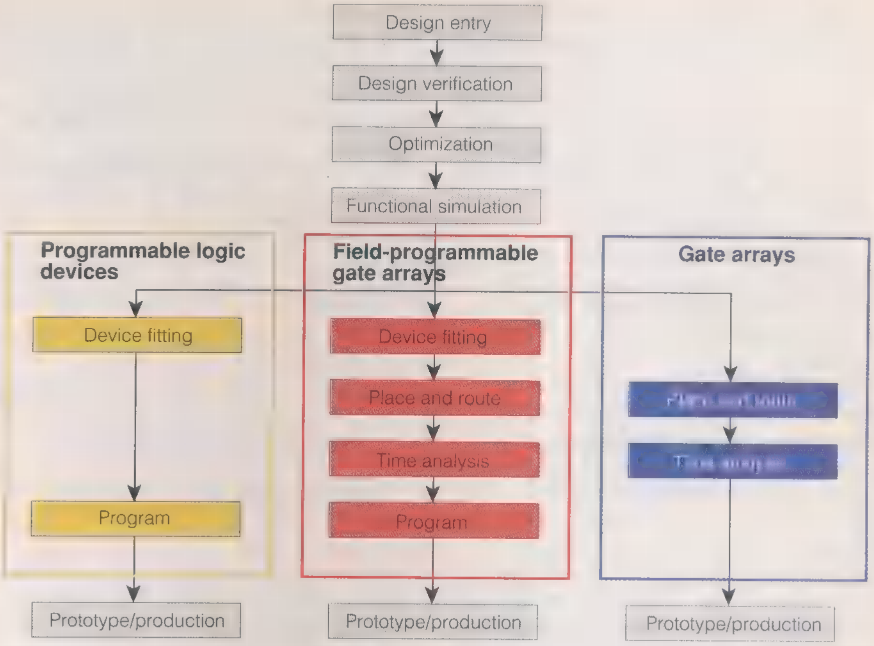
NEW FITTERS. As programmable-logic architectures continue to evolve and grow, those who produce EDA tools must confront mounting issues. The effort required to write a good fitter for an FPGA or large, complex PLD is at least an order of magnitude greater than the effort required for an older-style device; it may take six months to develop a fitter for today's devices versus a week for a traditional device. Also, fitters at present must be written on an architecture-by-architecture (and sometimes even device-by-device) basis.

In the past, when PLD design software depended on a simple sum-of-products equation to fit logic into a device, it was easy to reduce Karnaugh maps and state tables automatically to equations and directly map them to the targeted device. Given the diversity of complex architectures today, that approach is no longer viable.

Now, industry emphasis is on device-specific optimization algorithms that demand ever more detail about each and every chip architecture, including structural idiosyncrasies. Armed with those details, the optimization algorithm fits a logic design to a programmable device by means of logic transformation, logic partitioning, and signal placement and routing.

The concept of fitting is not new; in fact, it has been implicit in some tools for many years. In the case of PLDs, for example, the behavioral synthesis tool ABEL from Data I/O traditionally performs four fitting functions, namely pin assignment, node assignment, macrocell configuration, and control-term configuration. But today, all these functions have become more complex.

Pin assignment denotes assigning output logic to the pin that can best accommodate it; similarly, node assignment involves selection of appropriate points, or nodes, internal to the device. Neither task, however, is just a matter of finding any pin or node that fits an equation's logic, because some choices may be better than others when the assignments still left to be done are taken into account.



[1] The logic design tasks for complex programmable-logic devices and field-programmable gate arrays (PLDs and FPGAs) are a mix of traditional PLD and application-specific ASIC tasks. After the logic description undergoes generic optimization and functional simulation, it is subjected to fitter software where it aquires first architecture-specific and then device-specific characteristics.

Defining terms

Buried register: a register intended for use internally in a logic design.
Combinational (combinatorial, or combinative) logic: logic that provides a unique output state for each unique combination of input states.
Control term: a reset, output enable, or any other term that affects the general operation of a logic circuit.
Field-programmable gate array (FPGA): a device consisting essentially of arrays of logic gates that can have interconnections programmed between them so that they will perform a particular logic function.
Logic expander: a spare array of logic from which macrocells may obtain extra product-term inputs as needed.
Macrocell: a block of uncommitted logic circuits made up of small standard cells, such as flip-flops.
Partition: an area of distributed logic (whether a device or a resource within a device).
Partitioning: act of distributing the logic functions of a design among the target partitions (whether between multiple devices or between resources in a device).
Product term: the result of Boolean multiplication, such as the output of an AND circuit.
Product-term steering: the discretionary ability to assign product terms to a particular macrocell.
Programmable-logic device (PLD): a user-configurable device consisting of two or more logic arrays and possibly macrocells, too.
Sum of products: the addition of product terms obtained when, say, the output of an AND array is fed to an OR array.

Macrocell configuration refers to optimal use of all the programmable resources in a device's macrocell. The options include clock selection, choice of feedback, output polarity, and so forth. Control-term configuration likewise consists of choosing among options for output enable, register preset and reset, and so on. Larger, more complex PLDs require additional fitting.

Much is to be gained by automating all these fitting tasks. However, some fitters let the designer override automatic capabilities to enforce a design insight.

NEW DEMANDS. The fitting tasks thus far described are ones with which tools have long dealt. In the past few years, however, the new devices, made by companies like Atmel, Altera, Xilinx, Actel, and Plus Logic, have come to deviate from the older ones, mandating new and far more complex fitting capabilities. Most of the older devices had architectures that accepted sum-of-products logic directly; most of the newer devices do not. The older logic had a single programmable array where the newer have two or more. The older parts had no programmable routing; the newer do.

As a result, the demands on fitter software have ballooned. Newly required functionality includes:

- Two-level logic synthesis.
- Multi-level logic synthesis.
- Library and technology mapping.
- Design partitioning.
- Signal placement and routing.

Two-level logic synthesis embodies a variety of techniques for logic optimization, many of which are extensions of algorithms employed for simpler PLDs. Examples include register synthesis and phase assignment.

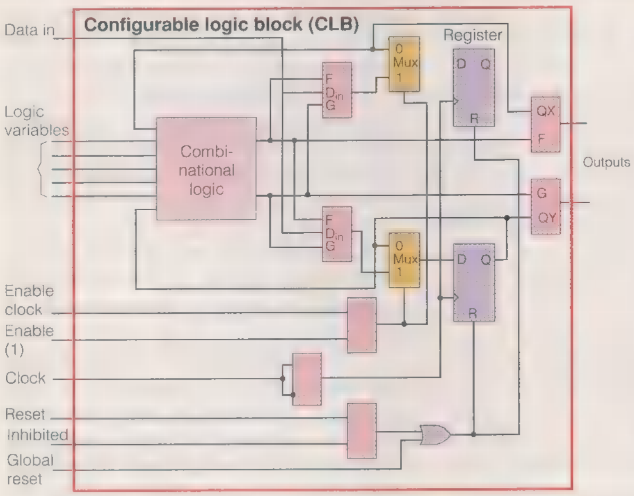
Register synthesis refers to the ability to implement logic described in terms of one register type in another. For example, designers often describe a counter in terms of D flip-flops, but it might map to some devices more efficiently if T (toggle) flip-flops are used. Xilinx LCAs, which are built around D flip-flops, can easily emulate registers designed around T flip-flops as well. In this instance, register synthesis would implement the logic in whichever type (or mix of types) was most efficient. Register synthesis tries various approaches, takes note of the register transformations resulting in the least logic, and selects the minimal logic in which a given register can be emulated. On the other hand, some PLDs support both types and therefore do not require register synthesis.

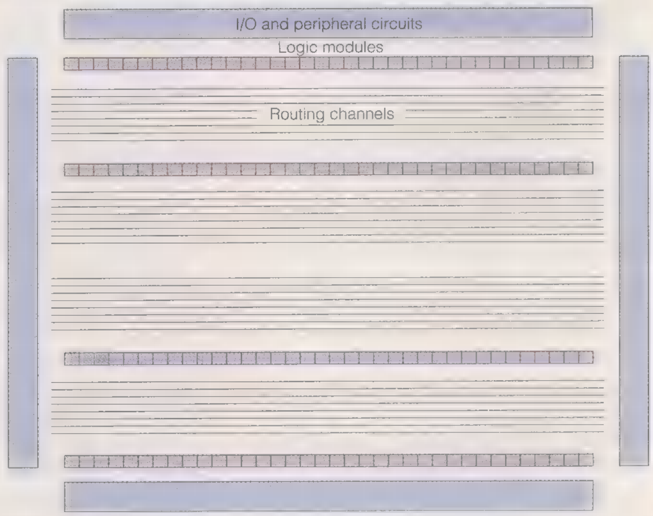
> Writing a good fitter is a substantial effort; it may take six months to develop one for today's devices

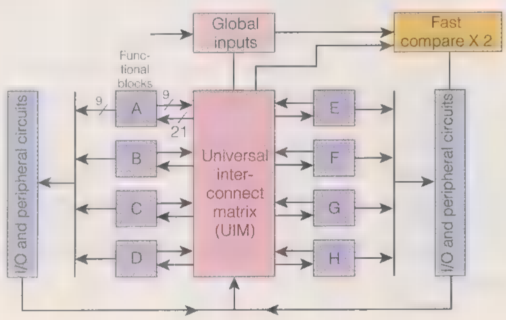
Phase assignment refers to the ability to determine whether the true or complemented version of the Boolean equation describing the logic design requires less logic, and to implement accordingly with the appropriate polarity conversion added to account for transformation. The judgment as to which complemented form constitutes less logic varies with the architecture, depending on the demand it places on product-term requirements, for instance.

Multi-level synthesis is the process of sorting a two-level design into three or more levels of logic. Like two-level synthesis, its goal is to reduce the amount of device resources required to implement the logic function within delay constraints. However, the techniques involved are entirely different. For multi-level synthesis, the primary technique is to mathematically determine the factors and subfactors in the design's Boolean equation; these determine the number of logic levels possible. Each factor or subfactor can be fanned out to multiple outputs or to other logic levels.

Often, increasing the number of logic levels reduces the required device resources but increases the delay in the logic path. Conversely, reducing levels of logic will speed up the design, but often will require additional device resources. The fitter must consider the target architecture, the design logic, and delay and utilization constraints







[2] Xilinx FPGA architecture comprises many configurable logic blocks (CLBs) and a periphery of I/O blocks. Each CLB (top left) has combinational logic and two registers. The Actel FPGA architecture (above) is based on rows of fine-grained logic modules separated by wiring channels. Plus Logic's FPGA, the Hiper 2020 (bottom left), has eight functional blocks (FBs) whose inputs and outputs are linked by a universal interconnect matrix (UIM).

imposed by the user. Multi-level synthesis is essential for efficient implementation in FPGAs, which as gate arrays are inherently multi-level at the silicon level.

TECHNOLOGY SPECIFIC. Mapping consists of processes that transform the relatively technology-independent output of the logic synthesis steps into an architecture-specific implementation. This may involve two steps: library mapping and technology mapping.

Library mapping re-expresses a generic logic description in terms of a specific library of components. For example, a truth-table description might be mapped to a netlist of AND and OR gates. Technology mapping takes the further step of transforming the netlist into the specific structures which exist within the target silicon; for example, a netlist might be mapped into a specific configurable logic block in a Xilinx Logic Cell Array. (Interestingly, this second mapping is an added burden for most FPGAs, one that is missing from gate array synthesis.)

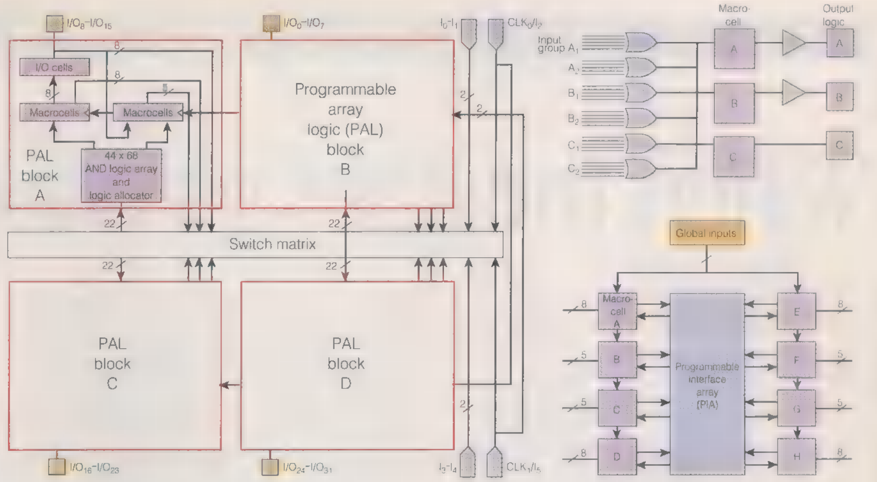
Design partitioning consists of having a fitter automatically divide a technology-mapped design among the multiple partitions inside a single device. This involves careful use, with an eye to the whole design, of resources like expander terms, global versus local feedback, and routing. It may be a difficult iterative task: assigning an equation to one partition may look acceptable until later, when another signal *does not* fit (maybe because of blocked routing resources)—which demands reassigning the earlier signal and trying again.

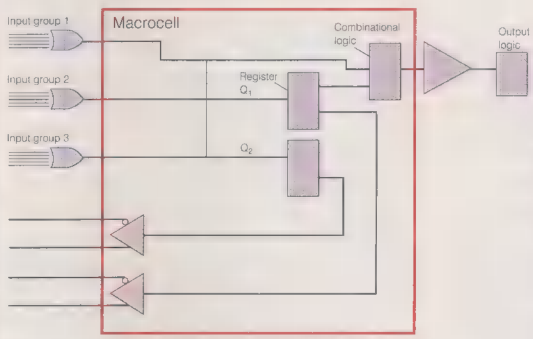
Block-based FPGAs require both multi-level synthesis and logic partitioning. Multi-level synthesis is essential to the fitting process for gate-array-like FPGAs; high-level logic partitioning is not. Conversely, partitioning is critical to fitting logic in complex PLDs and multiple-level synthesis is less so.

IN ITS PLACE. The final step, placement and routing, is truly a new challenge for fitters. In all older devices, if the logic "fit" (there were enough product terms, control terms, and so on), routability was guaranteed. But in newer large devices, everything-connects-to-everything architectures are impractical.

Signal placement and routing are a challenge because most complex architectures are not completely symmetrical. What works in one area will not work in another, and the fitter must know the particular target device's asymmetries to place and route judiciously. Plus, they involve a maze of interconnects and multitudes of interacting signals. So the fitter must now correctly interconnect logic as well as squeeze it all in.

For placing and routing, some of the classic ASIC algorithms and techniques are being used. These include the MIN CUT algorithm, bin packing, the greedy approach, and rip-up and retry. The MIN CUT algorithm reduces the number of signal routes used, while bin packing works on filling blocks or





[3] Typical of those complex PLDs categorized as having multiple-partitioned architectures, the MACH210 (top left) consists of four blocks of programmable array logic interconnected by a programmable switch matrix; in effect, each block is a separate PLD. An example of a product-term allocation architecture is Intel's 5AC312 EPLD (top right—shown here with only three of its 12 macrocells for simplicity). Each macrocell (A, B, and C) can take over a four-product-term group from, or lend it to, any adjacent macrocell. In contrast, product-term-joining architectures, like the Atmel 2500's (bottom left), share product terms; in addition to its four dedicated product terms, the combinational logic can share the product terms of two buried registers. Lastly, in expanded-term architectures like Altera's MAX EPM5128 (above), a macrocell can get extra product terms from a spare array.

partitions to the full before moving onto others. The greedy approach's cost functions mandate how solutions are judged to be optimal. With rip-up and retry the routing "logjams" for one particular placement must be broken up and routes torn up to allow adjustments to the placement. In the future, approaches like simulated annealing—a more recent method for finding optimal solutions—are likely to be used.

TO PROBE FURTHER. *Practical Design Using Programmable Logic* by David Pellerin and Michael Holley (Prentice-Hall, New York, 1991) comprehensively describes PLDs and FPGAs, initially through a historical perspective and then through today's design environments. Details on the MIN CUT algorithm, bin packing, the greedy approach, and rip-up and retry are found in the article, "An Efficient Heuristic Procedure for Partitioning Graphs" by B.W. Kernighan and S. Lin published in the February 1979 issue of the *Bell Systems Technical Journal*, while simulated annealing is described in the article "Optimization by Simulated Annealing" by S. Kirkpatrick, C.D. Gelatt Jr., and M.P. Vecchi in the May 13, 1983 issue of *Science*.

Many design automation topics will be covered at the 1992 29th ACM/IEEE Design Automation Conference, June 8-12, Anaheim, Calif., and at the 1992 European Design Automation Conference (EURO-DAC), Sept. 7-10 in Hamburg, Germany. Contact: IEEE Computer Society, 1730 Massachusetts Ave., Washington, D.C., 20036-1903; 202-371-1013; fax, 202-728-0884.

Another relevant meeting is the 1992 IEEE International Symposium on Circuits and Systems–Iscas '92, scheduled for May 10-13 in San Diego, Calif. Contact: Stanley A. White, 433 E. Avenida Cordoba, San Clemente, Calif. 92672; 714-498-5119.

ABOUT THE AUTHOR. Thomas R. Clark is president and chief executive officer of Data I/O Corp., Redmond, Wash., having previously held the positions of vice president of the design automation division and senior vice president of product operations. Before joining Data I/O in 1985, he was general manager of the software development products division at Tektronix Inc., Beaverton, Ore.

ACKNOWLEDGMENTS. The author would like to thank Michael Holley, Bob Hamilton, David Pellerin, and Steve Kaufer for their valuable insights and contributions to this work. ◆

When the lines go down

In a national emergency in the United States, organizations in affected areas will unite to repair or, at least, minimize damage

Ever since the U.S. court-supervised breakup of the Bell system in 1984, the nation's telecommunications infrastructure has evolved and diversified at an unprecedented pace. New suppliers and vendors have entered the field, each offering its own assets and services. New technologies, such as optical-fiber transmission and advanced signaling systems, have been developed and are being implemented at a rapid rate by major carriers. And new systems, based on emerging technologies like digital cellular radio, mobile satellite, and air-to-ground phones, are being put into place by independent companies.

But this rapid rate of change has also posed one critical, but often overlooked, challenge: its impact on telecommunications planning for national security and emergency preparedness (NS/EP). When the technology is advancing so quickly, how is it possible to ensure that NS/EP users will be provided with telecommunications service in every emergency and disaster, including natural catastrophes, terrorist attacks, and even nuclear war?

Like the general population of the United States, NS/EP workers have grown increasingly reliant on telecommunications to provide a warning of any impending disasters and to help workers respond to them. To ensure that kind of continued support, it is essential for both government and industry to stay alert to the state of the telecommunications art and to take whatever steps are necessary in providing the necessary facilities. Federal and state entities such as Congress and the courts, the Federal Communications Commission, and state public utility commissions, all have roles to play in that effort.

Disasters can affect telecommunications service in a variety of ways—from creating extraordinary levels of traffic to damaging or destroying parts of the service's infrastructure. In planning how to deal with disaster, industry, in the course of day-to-day business, can anticipate incidents that occur with a reasonably predictable frequency—such as tornadoes, floods, and cable cuts—and can provide for alternate routing and a rapid reconstitution of facilities. In most cases, the increasing capabilities and redundancies in the telecommunications industry work to aid that endeavor, cushioning the effect of individual network element outages so well that the average user remains unaware that anything has gone wrong.

Federal, state, and local planners, however, must look well beyond day-to-day situations to provide for other contingencies as well. They must consider such possibilities as political crises, military and terrorist attacks, regional disasters, and other incidents that could powerfully affect a broad segment of the public. The goal is to ensure that essential government operations continue through all emergencies, including those accompanied by heavy damage to the infrastructure, whether wrought by man or nature.

Most of the Federal government's telecommunications, even its so-called private networks, depend at some point on commercial carrier facilities. In the United States, all participants in the public switched network—service suppliers, equipment vendors, system integrators, legislators, regulators, and users—share in shaping the structure of the network. This contrasts with telecommunications in most other nations, where the government runs these networks (although privatization is a recent trend).

> National security and emergency preparedness concerns do not get priority from U.S. standards-setting bodies

With so many participants, the U.S. infrastructure of the public switched network is implemented with diverse modes of technology. Although that diversity can mitigate the effects of emergencies, it also creates uncertainties for Government planners charged with anticipating what measures and equipment will be needed to provide emergency telecommunications in all types of disasters. Industry developments, being primarily responsive to the needs of the majority of users, will not necessarily be responsive to the needs of NS/EP users. (The Federal government probably accounts for less than 5 percent of the traffic on the public switched network, and only a fraction of that traffic represents NS/EP users.)

Clearly, responding to what is needed for NS/EP telecommunications would be easier and less costly if standards guaranteeing interoperability of equipment in emergencies were established and followed. But since U.S. standards-setting bodies have been set up by industry—not by government, as in most other nations—NS/EP interests do not predominate in standards-setting activities. Also, compliance with those standards is only voluntary.

Adding to the difficulty of protecting NS/EP interests in the standards-setting process are the large number of different U.S. standards-setting bodies and the separate tracks that have evolved for standards for telephone and data. Finally, the pace of developing standards in the new technology areas does not always match the rapid pace of change in technologies and the national infrastructure.

PLANNERS AND DOERS. To ensure emergency telecommunications, a web of emergency structures, plans, and procedures are in place, with links from the local provider level to the national level. Involved in this web are:

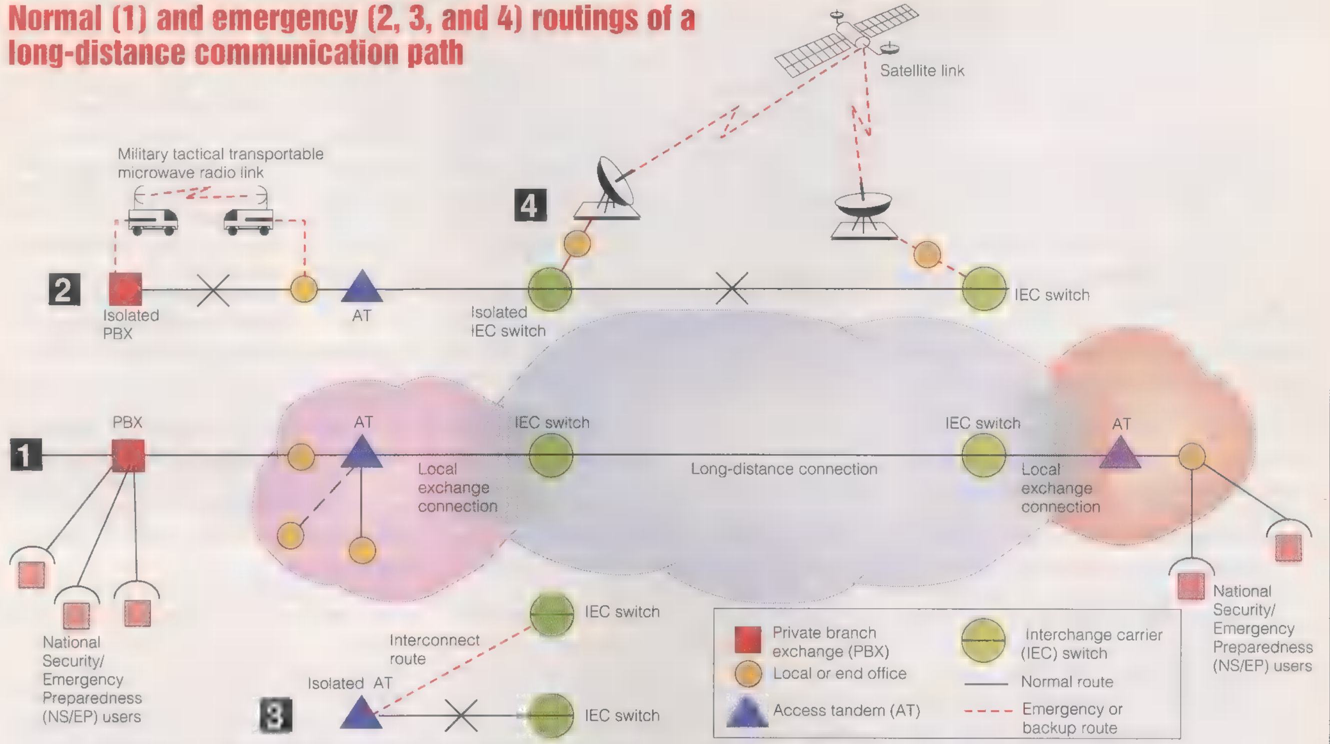
- Individual companies and providers.
- Regional and national corporate entities.
- State and local emergency management centers such as State Emergency Operations Centers.
- Federal regional telecommunications planners and managers like the General Services Administration and the Federal Emergency Management Agency.
- A national-level set of players from both government and industry, such as the National Communications System (NCS), Arlington, Va., and the President's National Security Telecommunications Advisory Committee (NSTAC), Washington, D.C.

The NCS is charged with ensuring the reliability and responsiveness of NS/EP telecommunications from a national perspective. Its dual mission is to assist the President and

Dennis Bodson National Communications System, Office of Technology and Standards
Eleanor Harris Mitre Corp.

 0018-9235/92/$3.00©1992 IEEE

Normal (1) and emergency (2, 3, and 4) routings of a long-distance communication path



A typical long-distance communication path [1] comprises a wide range of equipment types: the customer premises equipment (red and orange), the end office and access tandem switches of the caller's local exchange carrier (yellow and blue), one or more interexchange carrier switches (green), and the receiving local exchange carrier (pink and light orange). Means for coping with damage to the path will vary depending upon which part is damaged and how urgent it is to restore service. In [2], connectivity for an isolated National Security and Emergency Preparedness (NS/EP) facility can be restored by mobile or transportable assets such as the military tactical transportable (MTT) microwave radio link. In [3], a (leased) carrier can be interconnected to another switch as backup if an access tandem loses its connectivity to the long-distance switch that usually serves it. In [4], commercial communication satellites, which can handle large volumes of traffic over long distances, are especially suitable for reconnecting facilities separated by large bodies of water.

Defining terms

Access tandem: a switching system that concentrates and distributes traffic originating and terminating in one local access and transport area (LATA) and flowing among LATAs.

Intelligent network: a set of evolving telecommunications capabilities providing customized software-controlled network services. It can be configured by the customer independent of service provider activities.

Interoperable telemetry, tracking, and command facilities: a facility that combines the functions of a satellite operations center and telemetry, tracking, and command operations for all satellites within a family, such as three-axis or spin-stabilized satellites.

Orderwire: a voice or data circuit used by technical control and maintenance personnel for setting up, monitoring, and controlling communications systems and services.

Spin-stabilized satellite: a satellite that is kept in a stable orbit by exploiting gyroscopic action. The satellite normally includes a counter-rotating section on which the antennas are mounted so that they are able to point constantly toward the earth.

Three-axis stabilized satellite: a satellite that is kept in a stable orbit through the use of jet thrusters, one for each axis—yaw, pitch, and roll. The surface of the satellite facing the earth supports the antennas.

his key staff in exercising their wartime and nonwartime functions and responsibilities and in coordinating the planning for and provision of NS/EP communications for the Federal government under all circumstances, including crisis, emergency, attack, recovery, and reconstitution.

Within the NCS are 23 Federal member agencies and a Manager. The Office of the Manager of the NCS provides the support needed to carry out the NS/EP telecommunications responsibilities. Since the NCS was set up in 1963, the Office of the Manager has served as a focus for joint or cooperative action between the government and the telecommunications industry.

For example, the NSTAC was established in 1982 in anticipation of the impending change in the industry's internal structure. It serves as the Federal government's principal mechanism for working with industry in matters affecting NS/EP. Composed of the chief executive officers of key U.S. telecommunications companies, the NSTAC provides advice to the President from the telecommunications industry perspective, based on the deliberations of its various task forces on specific issues.

Further, through early efforts of the Manager of the NCS and the NSTAC, the National Coordinating Center for Telecommunications was created. The center, a unique organization because it is jointly funded and staffed by the Federal government and the telecommunications industry, serves as a watch center for national telecommunications. It participates in preparedness exercises and ensures priority provisioning or restoration of essential services in emergencies.

THE KEY. Readiness is key to reliability and responsiveness in emergencies. Preparation can be seen in the many measures that are built into the telecommunications infrastructure to minimize damage and service disruption as, for example, seismic design being required in the construction of California facilities.

Nationwide, emergency generators are located at most common carriers' key nodes, as are fuel reserves to operate the generators for a limited period of time. In most carrier networks, different paths are used to link cities and towns. Also, buildings that house critical users can request (at extra cost) multiple connections to the public switched network to provide for protection against failure of the primary access link.

Military organizations like the National Guard, along with some industrial companies, have a limited amount of mobile or transportable equipment that can be deployed when damage occurs. As part of a nationwide emergency telecommunica-

tions service program, the Federal government has developed a group of wireline and satellite system "augmentations," which might be used to help restore NS/EP communications in case of war or other major emergencies.

THE EQUIPMENT. Which of the augmentations or other equipment should be deployed in any emergency depends mostly on the urgency of restoring service and on the portion of the network that has been damaged [Fig. 1]. In industry, companies have a variety of methods to restore service to subscribers after damage or loss. At the national level, priority was given during the cold war years to procuring the means to serve NS/EP users under projected post-nuclear attack circumstances. Similar types of equipment are appropriate for use as well in major disasters, and Federal equipment may be required if infrastructure damage is massive or widespread. The possibility of the "big one"—a major earthquake in California or one along the New Madrid fault in Middle America—is not to be ignored.

The phone connection of Fig. 1 is a typical communication channel between NS/EP users. As such it can serve [illegible] a model to illustrate the various means (major equipment types) available for reconstituting the channel, depending on which segment is damaged. Customer premises equipment such as [illegible] telephone, fax, or computer—possibly connected through a private branch exchange—is usually owned and maintained by the user.

The local or end office and the access tandem (AT) belong to the local exchange carrier network serving the caller. Although there are many end offices in each such network, usually only one serves each user, and only one AT links to the user's long-distance carrier.

If the link between an important user's facility and its end office is severed, connectivity can be restored by military tactical transportable (MTT) radio assets [Fig. 2]. An example is the National Guard's mobile microwave unit AN/TRC-170—an augmentation to the public switched network in conjunction with earthquake response exercises. Such a mobile unit can restore one or two T1 circuits (one T1 carries 1.544 Mb/s, which is the equivalent of 24 voice channels).

MTT technology has been used in exercises to restore public switched network circuits, support standard telephone units, and secure telephones as well as facsimile and data devices. It has also been used to demonstrate the ability to link the Federal Aviation Administration's microwave network to the public switched network. A digital interface device was developed to allow connection of MTT equipment to the public switched network's digital facilities. This tactical radio equipment can operate in either line-of-sight or tropospheric scatter mode.

If the damage to the communications channel is to a segment connecting one network with another, one of the carrier interconnect augmentations would be the most appropriate way to restore service [Fig. 3]. One of these augmentations can accommodate larger volumes of traffic than the MTT can. As illustrated in Fig. 3, it can reconstitute an internetwork link by connecting the caller's AT to a different interexchange carrier switch than the one usually serving the connection.

Carrier interconnects use existing terrestrial facilities in nonstandard ways to provide alternatives to normal routes for NS/EP traffic. Interconnects can be set up between nodes of the same carrier or between two different carriers—for example, between two local or two interexchange carriers or between one of each type. The volume of NS/EP traffic on such a link can typically require capacities anywhere from a fraction of T1 to multiple T1s.

In planning for after [illegible] nuclear attack, the Office of the Manager uses carrier interconnects as appropriate. Locations for these interconnects utilize facilities judged unlikely to be damaged in [illegible] attack. However, interconnects can be used by NS/EP traffic in all situations where standard paths between switches would otherwise be blocked by damage.

In industry planning for day-to-day situations, certain interexchange carriers routinely lease capacity from another such carrier, which allows for occasional overflow traffic to be routed onto the other carrier's network. Carrier interconnect augmentations are generally made in advance, as they are contractual in nature and require considerable coordination in setting them up.

SATELLITES. Satellite systems can be the best option for link restoration under a range of circumstances, most especially when the long-haul segment of the channel has been interrupted—for example, when [illegible] enclave of operating telecommunications networks must be reconnected with the public switched network at a considerable distance [Fig. 4]. Such an emergency occurred recently when commercial satellite assets were used in restoring connectivity between Puerto Rico and the U.S. mainland after Hurricane Hugo roared through several Caribbean islands.

Many days after Hugo's passing, Roosevelt Roads Naval Station in Ceiba, Puerto Rico, the home of the Navy's south Atlantic command, still had only sporadic communications with mainland command centers. Deployment equipment, consisting of an equipment-laden truck and [illegible] 4.5-meter trailer-mounted antenna, was rapidly dispatched from Alaska to assist. After [illegible] 8000-km flight to the Caribbean in an Alaska National Guard C-130 transport, a three-man crew set up operations. Using a satellite that appeared higher above the horizon than the one that serves Alaska, lines strung into the nearby Navy communications command center linked the Navy with Alascom's extensive long-distance network.

In planning for scenarios of nuclear attack on the United States, the NCS office has enhanced the potential for interconnecting users through commercial satellites by augmenting some fixed commercial satellite system earth stations. The augmentations allow operations with satellites operating at 4–6 GHz within the domestic arc, and provide an alternative means of connecting selected switches in the AT&T Co. network.

Low-cost 4–6-GHz earth stations that are part fixed and part transportable have been developed and purchased as well. To control and monitor each of the two families of domestic satellites (three-axis stabilized and spin-stabilized), interoperable telemetry, tracking, and command (ITT&C) facilities have been acquired. Such control facilities would be needed only if the commercial satellite system's ITT&C facilities were not operating.

Emergency plans and procedures for the use of all these enhancements have been validated through exercises. The satellite system augmentations can be used at the discretion of the President under authority given him by Section 706 of the Communications Act of 1934, as amended.

WIRELESS. High-frequency radio plays a significant role in emergencies, [illegible] has been demonstrated many times in the past. Recently, the HF radio assets of Federal agencies have been organized for interoperability in a program called Shared Resources (Shares), whereby radio messages are relayed from point to point to reach destinations that would otherwise be cut off. The first operational Shares message was sent during the Hurricane Hugo emergency to Puerto Rico, carrying an urgent request for information on the medical supplies needed. A network of 22 stations from 10 Federal agencies linked the mainland to the disaster area.

In major disasters, cellular telephones as well as HF radio have proven valuable for emergency workers while downed subscriber lines are being replaced. The cellular handsets have the advantage of not being tethered and can function even where damage to local lines and poles is heavy. Operation depends, of course, on service being available in the area and on the serving mobile telecommunications switching office surviving intact. Cellular handsets were used in the Loma Prieta earthquake emergency in California when entry into damaged buildings was required to restore service. Obviously, cellular phones can be of immediate use to individuals who might otherwise be isolated in the damaged zone.

In both Hurricane Hugo and the California earthquake emergencies, mobile/transportable, self-contained telecommunications were called into play by cooperating agencies. A variety of equipment was used: satellite systems, cellular radio-telephone systems, other wireless telephone systems, and portable PBX equipment.

Almost universally cellular and HF radio equipment were valued by emergency response coordinators. For example, a dozen cellular phones were brought into the Sacramento-based California Emergency Operations Center for outgoing calls, freeing up the center's published numbers for incoming traffic. Where there were compatibility problems among the radio frequencies of cooperating agencies, cellular technology provided a simple solution. However, the network load at the center often saturated the local cell traffic capacity.

'PEOPLE' ACTION. Besides having equipment ready, success in dealing with emergencies depends critically on human preparation—extending from the provision of plans and procedures to the effective use of people and equipment.

The Office of the Manager of NCS provides the plans and procedures on which personnel training for contingencies is based. In the course of training, the procedures are tested, and both the team of people and the equipment they operate are exercised according to plan. The staff of the joint industry-government National Coordinating Center for Telecommunications, Arlington, Va., further assists in the initiation, coordination, restoration, and reconstitution of NS/EP telecommunications services or facilities. The center helps in exchanging information quickly and expediting NS/EP telecommunications responses.

The National Plan for Communications Support in Non-Wartime Emergencies provides standard operating procedures for the Office of the Manager of NCS, which receives external tasking from client agencies and member organizations as well. For authorizing priority treatment, important mechanisms have been identified, such as those in the new Federal Telecommunications Service Priority System. Early warning mechanisms also play a vital role in responsiveness, such as tracking and monitoring the progress of hurricanes and tropical storms by various means.

Industry has techniques for dealing with extraordinary levels of traffic that lead to network congestion and consequently to degraded service. Network management controls can be applied—for example, controlling the ratio of calls completed to calls attempted. Such management control was implemented for several days during the Loma Prieta earthquake emergency in California, blocking three out of four incoming calls to favor outgoing traffic.

However, public switched network management cannot at present give end-to-end priority to calls made by NS/EP users. The network cannot identify when an individual call is NS/EP traffic and carry that information across all elements that process the call en route—although such a capability may become available in the near future.

The proven method to preserve telecommunications capacity for critical users at their primary location is the use of private or dedicated networks. Truly private networks are extremely expensive and are

Maintaining power in emergencies

Although much can be done to protect a power system's generators against damage from earthquakes, storms, and other disasters, the same cannot be said for the system's power delivery. Generating plants can be sited away from geographic faults, surrounded by dikes (to keep them from being inundated during hurricanes), and braced against all but the most powerful of forces. But the lines that carry the power must go where the customers are, and economic reality says that every line cannot be installed in such a way as to make it disaster-proof. Therefore, although power utilities do what they can to prevent loss of service, their main emphasis is necessarily on developing plans for restoring that service as quickly as possible after the emergency has ended.

In the Northeast, where hurricanes and ice storms are the most common causes of outages, prevention consists mainly of trimming trees that overhang power distribution lines. However, in the West, where earthquakes are the big threat, the emphasis is on seismic bracing of buildings and substations and on installing substation circuit breakers and other gear that can withstand the swaying caused by ground motion without tripping.

But, for all areas, developing a disaster-recovery plan is another key pre-disaster activity. As Bruce Cocks, manager of the electric lines department at Long Island Lighting Co. (Lilco), Hicksville, N.Y., puts it, "You can't have a disaster and then develop a plan." The purpose of such a plan is to get repair crews to the right locations fast. According to Cocks, the fast part is easy. The challenge is to figure out what the right locations are.

Step No. 1 in any plan, therefore, is damage assessment. Different utilities go about it in different ways, but all agree that gathering information to determine the damage is paramount. Since power lines are spread out all over the service area, damage assessment takes a combination of driving, hiking, and even flying over the affected area in helicopters to note things like downed poles, fallen conductors, dangling transformers, or blown disconnect fuses.

Once the damage reports have been gathered at a central location, repairs can be prioritized and crews dispatched. Top priority, understandably, goes to restoring high-tension transmission lines. Those lines, which are carried on tall pylons above tree height, carry bulk power from generating stations to substations. On Long Island, according to Cocks, those lines are not usually damaged in storms.

In Texas, however, the picture is different. Leonard Wideman, manager of the Engineering Planning Division of Houston Lighting and Power Co., said that hurricanes there often spawn tornadoes, which create a lot of flying debris. If the debris gets blown against a tower, it can either damage it directly or add so much wind facing to it that the structure cannot withstand the wind's force.

Once the transmission lines are back in service, the main job begins: reconstituting the distribution system. Generally, the first rule is to make those repairs that will restore power to the largest number of customers with the least effort. Even more important is to restore power to hospitals and other medical facilities, police stations, water-pumping stations, and other essential parts of the infrastructure.

The final step in recovery is a post-disaster assessment of how well the recovery went so that the plan can be refined as necessary.

LOCAL VARIATIONS. Although the general approach to recovery for all power utilities is similar, details differ extensively. Lilco, for example, changes its entire organizational structure in emergencies, using the power substation as the main organizing unit. Pre-assigned teams of people report to the substations instead of their usual workplaces. In Houston, the service area is divided into zones, and the crews report to locations in those zones, some of which may be substations. In the area served by the Pacific Gas and Electric Co., San Francisco, which covers about two-thirds of California, crews simply report to their usual work locations, according to Lyman Shaffer, Pacific Gas and Electric's director of corporate security.

One thing that distinguishes earthquake-prone California from other locations is its approach to warehousing. Other utilities are able to keep their repair supplies and equipment in rather few locations, but, Shaffer points out, Pacific Gas and Electric now stockpiles its material at many sites because an earthquake could completely destroy any given warehouse and its contents.

Another difference among utilities is their attitude toward practice drills. While Lilco conducts two formal drills per year and Pacific Gas and Electric does one, Houston Lighting and Power prefers to conduct reviews at the operating zone level at the start of each year's hurricane season. Crews review their plans at those sessions, but they do not travel to their emergency duty locations.

One very important decision that every utility must make early in any emergency is whether it can handle the damage with its own crews or will need help from other utilities. If it decides to requisition help from its sister utilities via long-standing cooperative agreements, the entire management of the crisis must be handled differently. As Lilco's Cocks points out, the company's own crews must then act as managers and guides since the "foreign" crews are unfamiliar with the area. Also, a major effort must be made to find suitable accommodations for the visitors.

In all emergencies, of course, setting up housing and ensuring supplies of food and water must be planned well in advance. Arrangements are made with hotels, motels, grocery stores, and other important suppliers. In areas where hurricanes strike, the utilities typically have several days' warning so they can fine-tune their plans as the storm approaches. While technical crews make last-minute preparations, commercial representatives and power consultants are pressed into service to make the logistical arrangements. *—Michael J. Riezenman*

almost never used. Dedicated networks, which run on common carrier transmission facilities but are devoted solely to one user, are more reasonably priced, but they are still expensive since they require continuous payment for the provided channels, whether or not those channels are in use.

"Virtual" private networks, which utilize variable public switched routing instead of dedicated paths but reserve ■ certain level of capacity for network users, are much more reasonably priced. Currently, major research is being conducted by the Office of the Manager of NCS on how best to provide NS/EP users with priority treatment throughout the public switched network, call by call, to provide a potential long-term solution to ensuring NS/EP telecommunications in stressed environments.

LESSONS LEARNED. One of the primary service interdependencies, which was highlighted by Hurricane Hugo, is the one that exists between telecommunications and power [see "Maintaining power in emergencies," p. 43]. Emergency electrical generators routinely operate for hours and days, but emergency power needs during Hugo lasted for weeks or months in the islands, where closed airports hindered delivery of emergency equipment.

In the Carolinas, the loss of commercial electric power was the main source of trouble in continuing and restoring telecommunications service. Communications failures after the storm were due mostly to failure of emergency power systems. In general, while the switched networks in Puerto Rico and the Carolinas remained operable after Hugo, they became extremely congested, and users experienced long delays in receiving a dial tone and completing calls.

Some network elements proved more vulnerable than others to storm damage. Many island microwave towers were misaligned; earth station terminals and antennas were severely damaged; and telephone poles and lines were downed by falling trees. Further damage to cables in Puerto Rico occurred afterward, through lack of coordination between power and telephone authorities during debris removal and restoration efforts.

However, as in the California earthquake disasters, automated telephone switches survived virtually intact.

In the California earthquake, major industry facilities, switches, end offices, and local distribution plant proved less susceptible to damage than the commercial power system. Most communications operations were sustained by batteries and backup emergency generators. Emergency planning and earthquake exercises paid off by reducing confusion and making early efforts to respond possible.

Also in evidence was the high professionalism and public service ethos of private industry through the many NSTAC member organizations who volunteered hardware, parts, supplies, and other assistance through the National Coordinating Center for Telecommunications. One company, McCaw Communications Inc., Kirkland, Wash., provided over 1200 mobile/portable cellular telephones for free local and state government use in the early stages of the emergency.

WHITHER NOW? Emerging technologies can be viewed as a blessing and ■ bane. While most industry members feel that new developments tend to enhance survivability in the long term, some say that certain trends brought about by new technologies increase the vulnerability of the public switched network. Specific incidents, such as last year's extended outages in carrier networks implementing a new signaling system, can be viewed with alarm or accepted as indications that setbacks are not always avoidable in achieving long-term improvement.

The rapid change in technology can introduce waves in the NS/EP planning process ■■ well. For example, through recent industry developments, separate, common-channel signaling can result in more efficiency and economy of operation than that provided by the older "in-band" call signaling. But wherever a carrier has implemented the new Signaling System 7 (SS7), a second network of switches and databases, using packet-switched technology, is required for setting up the call. Thus, the trend toward SS7 use has created a new problem in NS/EP planning since it is now necessary to ensure the restoration of two channels, the signaling channel as well as the one for communications.

> A web of emergency structures, plans, and procedures insure U.S. telecommunications in any crisis

However, emerging technologies show great potential for improving capabilities to assist in emergencies. Among other developments is the Intelligent Network, made possible by the implementation of SS7, whereby a call could theoretically be routed to ■ specific NS/EP individual, regardless of that user's geographical position on the public switched network. However, an NSTAC task force addressing the Intelligent Network has observed that the use of any NS/EP user identification and location capability has not yet been universally adopted by industry. Until it is, ubiquitous access cannot be provided.

In another area, the NSTAC is assisting the government with ensuring NS/EP user call-completion with minimum delay during network damage or congestion. A task force has identified capabilities in the public switched network today that could help, as well as key elements required to achieve more capabilities. The development of new industry standards would be required, ■■ well as new hardware and software.

In still another area, government and the NSTAC have recently noted that NS/EP requirements are not being considered in the development of new wireless digital technologies—a part of the mushrooming mobile communications sector. The use of low-rate compressed voice for spectral efficiency on these networks will inhibit the use of conventional modems for data services. Tools of the NS/EP user such ■■ PCs, facsimile, and secure telephone units, which operate well on current analog mobile systems, may not be able to work on the new mobile systems. That area represents still another challenge, this time with a narrow time window for action.

Standards involvement in all of the above areas is very essential. The government needs to represent NS/EP interests in the many bodies that are setting industry's standards. Moreover, it needs to do it quickly enough to have some impact. For its part, industry needs to see that the many standards-setting bodies are adequately coordinating with one another. There is also ■ need to establish new standards bodies as soon as technological developments raise interoperability concerns.

TO PROBE FURTHER. "Technical challenges to ■ decentralized phone system," September 1990, *IEEE Spectrum*, by Trudy E. Bell, the third in ■ series, describes technical advances and changes in the regulatory climate in U.S. telephony since the court-supervised divestiture of AT&T Co. Earlier articles in the series, "Telephone challenges: a plethora of services," July 1990, by Tekla S. Perry, and "New pay phones hit the street," May 1990, by Glenn Zorpette, shed light on the proliferation of services and equipment available as a result of deregulation.

An article by John G. Grimes and Kenneth B. Boheim, "National System Provides Survivable Communications" in *Signal*, March 1990, described national level activities at that time. Earlier, concerns of the military were described in "The Earthquake Threat," by Peter Grier in Military *Forum*, January/February 1989.

ABOUT THE AUTHORS. Dennis Bodson (SM) is assistant manager for the National Communications System Office of Technology and Standards, Arlington, Va., the organization of the Federal government that is charged to provide needed telecommunications support in emergencies via the national telecommunications infrastructure.

Eleanor Harris is a member of the technical staff of Mitre Corp. McLean, Va., a not-for-profit company that provides technical support to government. ◆

Maxwell's grand unification

The notion that electromagnetic effects travel through space at the speed of light was a stroke of genius

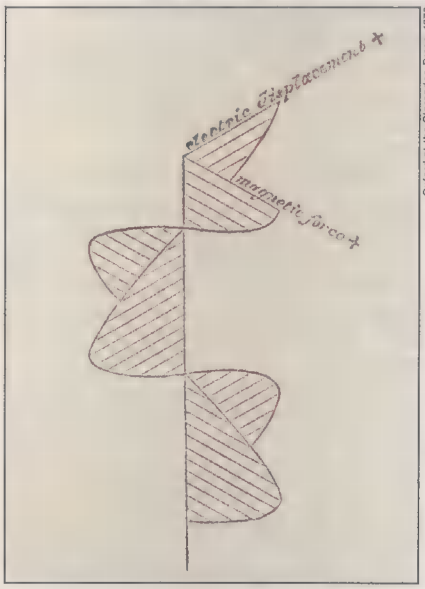
In the second half of the 19th century, theory was starting to grapple with electromagnetic phenomena. The battlefield soon drew two Scotsmen, both well armed with mathematical skills. One, William Thomson, was to fall by the wayside after some limited successes, though he later became Lord Kelvin. But the other, James Clerk Maxwell, succeeded.

In a series of letters to Thomson in the middle 1850s, Maxwell outlined his ideas on where to pick up the path to a theory of a "whole mass of confusion," as he called it. He felt the key lay in the *electrotonic state*, Michael Faraday's name for inductive effects. Maxwell's first step toward an electromagnetic theory, therefore, was a paper in 1856 on this vague, ill-formed concept. He wrote this paper, "On Faraday's Lines of Force," when he was just 24. For it, he borrowed Thomson's 1847 idea of calculating a vector from another vector by means of the curl vector operation (the word *curl* being Maxwell's contribution), a move important to this day. Next followed "On Physical Lines of Force," published during 1861–62, which further clarified the electrotonic state in terms of a mechanical model and introduced yet more mathematical machinery, in particular, the integral theorems of Cambridge mathematician George Stokes, a friend of both Maxwell and Thomson. Finally, in 1865, came "The Dynamical Theory of the Electromagnetic Field."

In this third paper, with the mechanical model now gone, Maxwell presents his theory in essentially its final form. What had started in Faraday's wonderfully imaginative mind as the electrotonic state had become Maxwell's *electromagnetic momentum*. Today it is called the *vector potential*, a term first used by Maxwell in 1871. The curl of the vector potential is the magnetic field vector. Despite this, the third paper (like the second) would look well-nigh unintelligible to a modern electrical engineer used to vectors because it presents the theory as 20 equations, in a hodge-podge mix of component and quaternionic notation.

PROPAGATING FIELD. But the physics is all there, and the conclusion is astounding: electromagnetic effects travel through space at the speed of light. Indeed, light itself is a propagating transverse electromagnetic field [see illustration]. By showing the science of light and optics is merely a branch of electromagnetism, Maxwell had achieved the second great unification in physics. (The first was Newton's unification of terrestrial and celestial mechanics.) Here, too, Maxwell stated that the energy of electromagnetic phenomena resides not just in electrified bodies, but also in the space surrounding such bodies.

Maxwell's famous equations, which summarize the electrical knowledge of his day, state that electric lines of force are created either by electric charge or by time-varying magnetic fields, while magnetic lines of force are created either by electric currents or by time-varying electric fields. This last part was uniquely Maxwell, as it represents his famous *displacement current*. That a time-varying electric field could produce a magnetic field, just like a conduction current in a wire, was an audacious statement because there was no evidence for it.



Oxford at the Clarendon Press, 1873

Today, electrical engineering and physics professors "derive" the displacement current term by showing that, without it, the rest of the equations are inconsistent with the conservation of electric charge. Maxwell did not, but his genius guided him to the correct result anyway.

Any inconsistency with charge conservation is all but undetectable in a closed circuit—and only closed circuits had been studied as, after all, what sense could an open electrical circuit make? But with the displacement current, an open circuit does make sense, and the displacement current is what gives life to radio, television, and radar waves, light, and X-rays, all of which are propagating electromagnetic energy.

At the time of his death of cancer at 48, in 1879, Maxwell's theory of electricity and magnetism was one of several. Its correctness was established only in 1887, when the German Heinrich Hertz discovered electromagnetic radiation at microwave frequencies, as predicted by Maxwell. Others, though, had not had to wait for Hertz; these true believers were members of a small group that has become known as the Maxwellians. They included the Englishmen John Poynting and Oliver Heaviside who, in 1883, simultaneously discovered how Maxwell's theory predicts that a propagating electromagnetic field transports energy through space.

Since the pioneering work of the Maxwellians, Maxwell's equations have been studied for over a century, and have proved one of the most successful theories in the history of science. For example, when Einstein found that Newtonian dynamics had to be modified to be compatible with the special theory of relativity, he also found that Maxwell's equations were already relativistically correct. Magnetic effects are, after all, relativistic effects produced by moving charges, and so Maxwell had automatically built relativity into his equations.

TO PROBE FURTHER. For the development of Maxwell's ideas, see Jed Z. Buchwald's *From Maxwell to Microphysics: aspects of electromagnetic theory in the last quarter of the nineteenth century* (University of Chicago Press, 1985). For what happened with electrodynamics during the two decades after Maxwell's death, see Bruce J. Hunt's *The Maxwellians* (Cornell University Press, 1991). For more on Oliver Heaviside, see this author's *Oliver Heaviside: Sage in Solitude* (IEEE Press, 1988).

ABOUT THE AUTHOR. Paul J. Nahin (SM) is associate professor of electrical engineering at the University of New Hampshire in Durham. His new book, *Time Machines: fact and fiction*, will be published later this year by the American Institute of Physics. ◆

Paul J. Nahin University of New Hampshire

0018-9235/92/$3.00©1992 IEEE

Through a bat's ear

The bat's sonar performance is encouraging researchers to disregard conventional distinctions between time and frequency domains

Bats are the only mammal to inherit, rather than acquire, the ability to fly. They navigate and capture insects in the dark by means of echolocation, an active sonar that scientists have scrutinized for decades for clues on how to refine radar and sonar systems. Recent experiments sponsored by the Office of Naval Research, Washington, D.C., show how the bats' acoustic imaging combines time- and frequency-domain operations in a variety of ways. One upshot is a design for a signal processor, now being put on a chip, that models the bat's acutely sensitive auditory neural system.

MID-AIR INTERCEPTION. Some bats home in on their targets by emitting chirps at ever shorter intervals, as is evident from photographs and ultrasonic tapes [Fig. 1]. Most species of bats transmit brief chirps of 0.5–10 ms at relatively long intervals. The squeaks are frequency-modulated in the ultrasonic range of 15–150 kHz. For instance, the fm signals of the big brown bat, *Eptesicus fuscus*, sweep two frequency ranges simultaneously—50–22 kHz or so in the first harmonic, 100–44 kHz or so in the second. These fm chirps are short, and each one yields a strobe-like image.

Other species of bats emit compound signals, in which constant-frequency (cf) signals lasting up to 100 ms are attached to the fm signals. For instance, the horseshoe bat, *Rhinolophus ferrumequinum*, emits a cf signal at about 83 kHz between fm chirps of 83 to 65 kHz. These bats use the cf components as narrowband signals, with the individual frequency serving as a carrier for the frequency and amplitude modulations that the target's fluttering imposes on echoes.

For a bat to classify targets, it has to characterize glints within an echo from various surfaces of the insect, for instance, its head and wing tips. The insect's flutter rate, about 10–100 Hz, is important. The horseshoe and other cf bats prefer fluttering targets, which they identify by registering the frequency of cf echoes with great accuracy. They use high-Q bandpass filters (Q values of several hundred) as a sort of spectrum analyzer that "zooms in" to expand the display of the cf frequency region.

James A. Simmons, Prestor A. Saillant, and Steven P. Dear Brown University

In contrast, purely fm creatures, like the big brown bat, use their sounds as broadband signals, deriving images by integrating echo information across many frequencies. They determine the distance, or range, of targets from the delay of fm echoes (5.8 ms/m). In an echo with a known signal-to-noise ratio of 36 dB, the brown bat can detect delay changes of about 40 ns. A theoretically ideal receiver would do about the same. This feat requires parallel estimation of delay at many frequencies within the fm sweeps, followed by the efficient pooling of those estimates across frequencies.

TELLTALE CLUE. What's more, fm bats determine the target's shape very reliably, and thereby hang the most interesting clues to the echo-processing algorithms in the bat's brain.

At the top of Fig. 2, the range separation, Δr, between the moth's head and its wing is about 9 mm, resulting in a 50-μs echo time separation, Δt. These echo components overlap because flying insects are such tiny targets—the glints are close together so the sonar sound lasts longer than the echo separation.

Furthermore, the integration time for echo processing by the brown bat is about 350 μs. Consequently, echo components only 50 μs apart will be smeared together into a single, spectrally complex echo with only one directly recognizable delay, t. This the bat measures to perceive target range, r.

The interference spectrum of the overlapping echoes is what represents the echo time (or range) separation of the glints. But despite the rather long receiver integration time of 350 μs, the brown bat perceives the actual echo time, and not merely a spectral coloration of the echo. Somehow the bat converts the echo spectrum back into the echo time separation.

FM ECHOES AND RANGE. The bat's ear of course picks up both the emitted sound and its echo. In the animal's auditory system are thousands of parallel bandpass filter "channels"—auditory receptors and their associated auditory neurons—tuned to different frequencies across the whole ultrasonic band of sounds. The spacing of their center frequencies defines a frequency scale that is used for encoding the fm sweeps as spectrograms.

Spectrograms are usually displayed with a linear frequency scale, but these emission and echo spectrograms [Fig. 2, bottom] instead are plotted on a hyperbolic vertical frequency axis that corresponds to the frequency-mapping scale in the brown bat's auditory system. As the fm sweeps of the chirp pass through the bandpass filters, they evoke an auditory spectrogram (the sloping shaded areas marked "excitation" in the bottom left chart). This excitation then triggers a volley of neural discharges (the filled dots of the chart), equivalent to a neural spectrogram of the sonar transmission. This spectrogram serves the bat as a template for processing echoes.

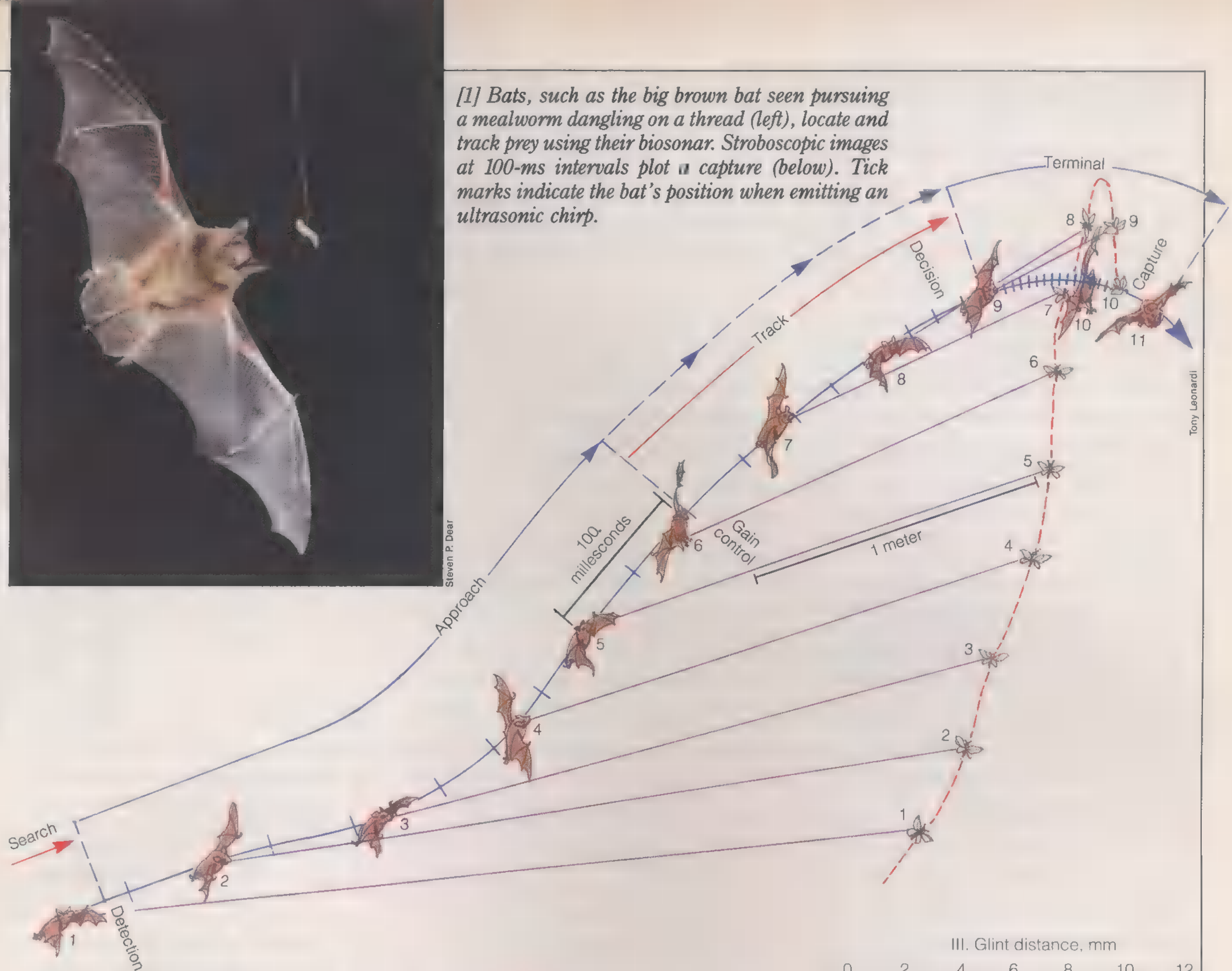
When the bat's echo, altered by contact with the target, arrives several milliseconds later, it, too, evokes a volley of neural discharges. The echo and emission spectrograms are distinguished by the time that elapses between emission and echo at each frequency in the fm sweeps. The bat determines target range from these spectrogram delays by storing the volley of discharges representing the emission and then comparing it with the pattern formed upon reception of the echo.

The storage mechanism is a population of neurons that together respond at times ranging from about 5 to 35 ms after the emission. This spread of response latencies retains the emission spectrogram for up to 35 ms. These neurons form a system of parallel, multitapped delay lines—one delay line for each auditory frequency channel.

When an echo is received, it evokes discharges with a short latency that converge on longer-latency neurons still responding to the transmitted sound. Higher-level neurons (those located at a site to receive the convergence) register a coincidence between the discharge in response to the echo and some of the discharges in response to the earlier transmission. The probability of coincidence is greatest in those higher-level neurons where the latency delay of the discharge to the transmission equals the acoustic delay of the echo. The bat's estimation of the echo delay, t, consists of the ensemble of spectrogram delays across different frequencies in the fm sweeps, as represented by coincident-specific higher-level neurons (acting like tapped delays).

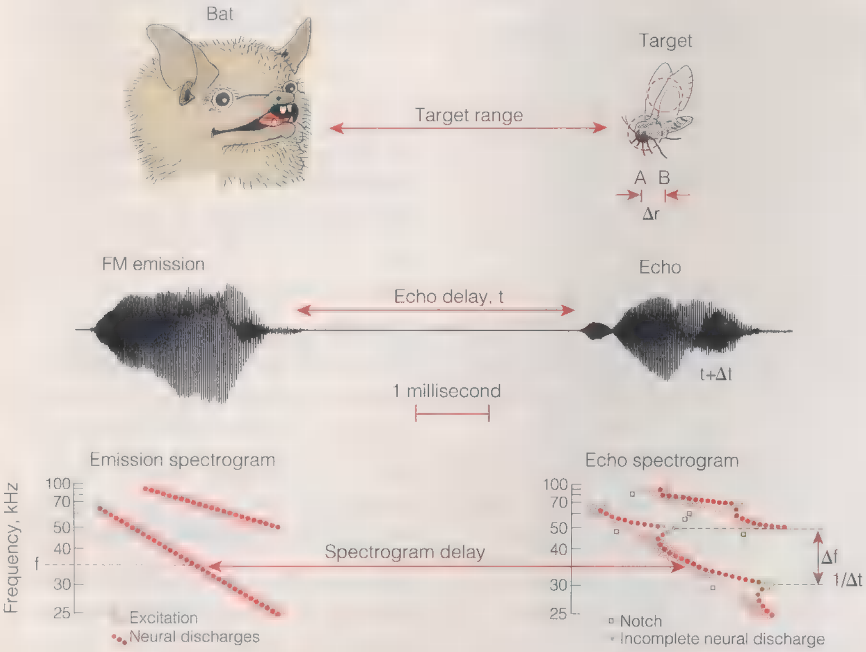
TARGET SHAPE. Recall that the bat's auditory system has a 350-μs integration time. A moth that reflects two echo components

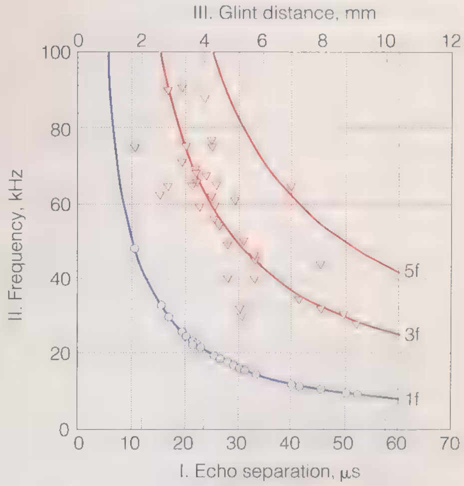
0018-9235/92/$3.00©1992 IEEE



[1] *Bats, such as the big brown bat seen pursuing a mealworm dangling on a thread (left), locate and track prey using their biosonar. Stroboscopic images at 100-ms intervals plot a capture (below). Tick marks indicate the bat's position when emitting an ultrasonic chirp.*

[2] *A bat compares a 2.5-ms emission with its echo (below) to determine not only the range of the target but also its shape—the spacing of glints from head A and wing B (Δr). These two components are returned in the echo at delays t and t + Δt. When plotted against a hyperbolic frequency axis, the spectrogram of the echo displays the bat's possible neural responses. The bat uses notches (an absence of neural excitation) to pick out glints within the overall large echo return. (Source: James A. Simmons)*





[3] *The brown bat's auditory system might do a frequency-to-time transform to sort overlapping echoes. This determines spacing between two glints of a moth's return by using the frequencies and spacing of notches (Δf in Fig. 2). The curves (1f, 3f, 5f, above) represent frequencies (axis II) of notches for different echo separations (axis I). Many of the bat's neural responses are tuned to two frequencies (circles and triangles), and the location of neurons on the bat's hyperbolic frequency map (axis III) decodes the spacing.*

50 μs apart will therefore evoke just one volley of neural discharges in the bat's auditory spectrogram. So what betrays the fact that the echo contains two components? The clue is the placement of spectral peaks and notches along the spectrogram's frequency axis.

Notches are caused by spectral interference and appear at regular frequency intervals, according to the different times of arrival of echoes from different glints [Fig.3]. To the ear, they indicate brief dips in the amount of auditory receptor excitation occurring at specific frequencies. In turn this leads to either the nonoccurrence of the neural discharges (open circles in the echo spectrogram) or their later-than-usual occurrence (the rightward drifting of solid dots around 30, 50, 70, and 90 kHz). The net effect: the scalloped appearance of the echo spectrogram.

The neural code for spectral notches is only part of the imaging process because the bat perceives the second glint itself from the spectrum. This can be demonstrated by delivering echoes to the bat just for the first glint, but filtering these echoes to include spectral notches at specific frequencies to mimic the presence of an additional echo component. The bat registers the target ■■ having two glints.

BAT-INSPIRED DESIGN. Experimental studies of bat sonar have progressed to the point of developing a model sonar receiver based on the bat. Algorithms that break new ground by mixing time- and frequency-domain techniques to reconstruct target shape from echoes have already been tested successfully in ■ computer at Brown University. Now the goal is to develop ■ very large-scale integrated (VLSI) chip capable of real-time operation with these algorithms.

The model of the brown bat's sonar has three stages: ■ front end that mimics the inner ear in order to encode waveforms; a system of delay lines that determine echo delays; and another system that determines the spectrum of echoes and from it estimates the time separation of echoes from multiple target glints.

Collectively these stages carry out two signal-processing operations in parallel to assess target range and shape—spectrogram correlation and transformation (SCAT). Their outputs are then merged into one image. During spectrogram correlation sonar emissions and echoes are encoded and the overall delay of echoes is determined; spectrogram transformation then determines target shape from the spectral changes that are caused by the target.

Like the bat, the SCAT process picks up each sonar transmission at the moment it is broadcast and represents it as ■ spectrogram—and does the same for echoes when they are received. Every frequency in the emission and echo is registered within 81 parallel bandpass filters that mimic the frequency analysis by the bat's inner ear. The center frequencies of these filters are arranged on a hyperbolic scale of frequency of 20–100 kHz, such that equal time increments separate the periods that correspond to adjacent center frequencies. For 81 filters, the period increment is 0.5 μs. Thus the 20-kHz channel has a period of 50 μs, and the adjacent channel (20.2 kHz) has a 49.5-μs period and so on.

These bandpass filters are tuned with different degrees of sharpness to various frequencies, with filter Q-values increasing from 5 at 20 kHz to 25 at 100 kHz to mimic values observed in fm bats. The output of each bandpass filter is half-wave rectified and then smoothed with ■ lowpass filter at about 1 kHz, thus forming a series of 81 envelopes representing the typical excitation spectrograms for emission and echo.

After being segmented into 81 overlapping bands, the sonar transmission is coded into digital pulses (analogous to neural discharges in the bat's auditory system). The pulses are triggered by the filtered envelope in each frequency channel to mark the time at which the fm sweep passes through the corresponding filter frequency. Following each filter is ■ multitap delay line for storing the digital pulses representative of the transmitted sound.

A sonar receiver based on the brown bat's auditory system has already been simulated

When an echo is received several milliseconds after transmission, the same bandpass filters are activated and similar digital pulses are triggered by their outputs. But these echo-evoked pulses are not sent through the delay lines. Instead, each one is simultaneously compared with (is used to gate) all the taps in the delay line, the goal being to locate the pulse representing the earlier transmission as it travels from one tap to the next in line.

The tap specific to the transmission can then be identified ■■ any coincidence between the emission and echo pulses. The overall delay of the echo, or the target range, is estimated by averaging the coincidences among all the parallel delay lines.

The target's shape consists of the range spacing of glints—represented by the spectral interference of echoes from the glints, resulting in peaks and notches at specific frequencies. A spectral notch in the echo results in the absence of an emission-echo coincidence at that specific frequency. By finding all these notch and peak frequencies, the SCAT model determines how the target has influenced the echo spectrum. Then from these notch frequency values, the model estimates the time difference between the two delays required to produce the notches, which is directly related to the distance between the glints returned by the target.

One version of the SCAT model, as diagrammed in Fig. 3, mimics the big brown bat's ability to locate spectral notches and interpret these fast by virtue of the hyperbolic relation between sound frequencies and location of specific neurons. The SCAT model synthesizes special oscillatory functions, based on damped cosines, that are "written" in each delay line. When an echo is received and all the oscillating functions are present, their average is approximately flat, or zero, and no second glint emerges in the image. But if specific oscillating functions are missing because of the nature of the echo's spectrum, their average is not flat but peaked at certain delays. These peaks constitute a spectrally derived image of the location of the second glint relative to the first glint with resolution superior to that of an ideal, cross-correlation receiver.

What next? The SCAT process is a general-purpose deconvolution technique that, thanks to the bat, disregards some conventional distinctions between time and frequency domains. The algorithm, with its hyperbolic relation, engenders a simple geometric structure ideal for VLSI chips. This is now being pursued jointly at the California Institute of Technology in Pasadena and at Brown University.

Possible applications of these chips are in sensing and communications, including locating and classifying multiple radar and sonar targets, determining propagation times of seismic phenomena, and distinguishing multipath reverberation in complex acoustic environments.

TO PROBE FURTHER. A June 1990 article by Nobuo Suga in *Scientific American* describes neural mechanisms of sonar in the mustached bat. Articles by James Simmons in *The Journal of Comparative Physiology* (Vol. 166, pp. 449–70, and Vol. 167, pp. 589–616, 1990) describe in detail the bat's reconstruction of images.

The *Journal of the Acoustical Society of America* and the *IEEE Transactions on Signal Processing* are other general relevant resources.

ABOUT THE AUTHORS. James A. Simmons is a professor in the Section of Neurobiology and the Department of Psychology at Brown University, Providence, R.I. He has been pursuing research on bats since 1965.

Prestor A. Saillant is a doctoral student at Brown. He previously worked at Raytheon Corp.'s Submarine Signal Division, Portsmouth, R.I.

Steven P. Dear is a research assistant professor at Brown, having previously worked in the laboratory of Nobuo Suga at Washington University, St. Louis, Mo. ◆

A catalyst for U.S. competitiveness

Programs of the Commerce Department's Technology Administration are stressing cooperation with industry and academia

Only recently has the Federal government had a unit just for technology issues: the U.S. Commerce Department's Technology Administration, created by Congress in 1988. This fledgling organization has already exercised its leadership by launching a product data exchange standards initiative, coordinating the U.S. response to Japan's intelligent manufacturing systems research proposal, and playing an active role in promoting technology transfer.

But the Commerce Department, Washington, D.C., has never been in a position to influence the R&D funding levels of other government agencies or prioritize technologies. Nor has Commerce itself been a major funder of R&D. The department's role instead has been to understand innovation as a system and try to make that system work as well as possible.

As a result, Commerce programs reflect different approaches. In some cases, the department acts as an *advocate* for industry within the Federal government. A good example of this role is its contribution to a recent Congressional resolution designed to clarify the tax treatment of good will and certain other intangible assets, including software. The bill proposes to extend the amortization period to 14 years. Believing that this would inhibit the competitiveness of the software industry, the department proposed an amendment that would ensure that software continues to be treated in accordance with current practices.

BALANCED AND EQUITABLE. The Commerce Department also acts as an advocate for industry with foreign governments. For example, Japan's Ministry of International Trade and Industry (MITI), Tokyo, proposed an international cooperative R&D program in intelligent manufacturing systems (IMS) in late 1989.

As initially structured, the program appeared to seek to access the best U.S. and European manufacturing technology without offering anything in return. So to ensure that IMS and other such international programs proceed in a balanced and equitable manner, IMS was brought under the provisions of the 1988 U.S.-Japan Science and Technology Agreement. Through that pact, the proposed program was to be restructured and a decision made as to whether the United States should participate in it. The Commerce Department stepped in to help coordinate the U.S. industry response.

As a result of extensive discussions with the private sector, the United States has entered into a feasibility study on IMS that is expected to last approximately two years. The U.S. government also drafted "Terms of Reference" that were accepted by all participants in the IMS program—Japan, the European Community, Canada, Australia, and the European Free Trade Association.

SHARING THE BREAKTHROUGHS. Hundreds of Federal laboratories, owned and/or operated by various Federal agencies, produce not only valuable basic research but also technological breakthroughs in a great many fields.

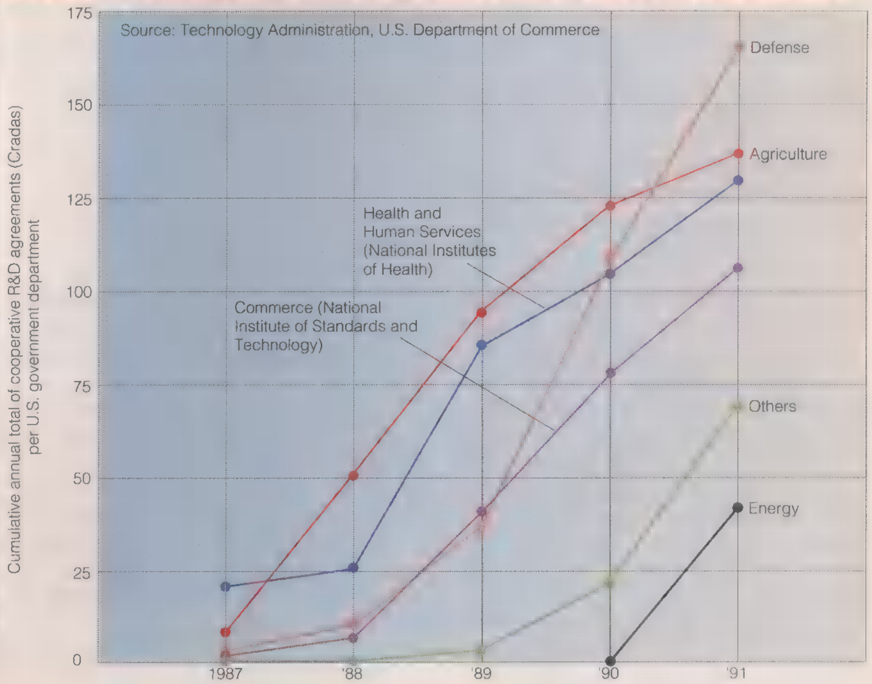
In the past, little effort was made to share the fruits of this work with the private sector—or even to identify what research and technology might be relevant for commercial products and processes.

More recently, the Federal government has taken several steps to institute an "open door" policy that features cooperation and partnership arrangements between the laboratories and small businesses, universities, and state and local governments. Another part of this phenomenon has been a conscientious effort to provide incentives for Federal scientists so that they can share in the rewards when their discoveries become marketable inventions.

To further encourage the private sector's commercialization of Federally funded R&D, the Federal Technology Transfer Act was passed in 1986. The act permits Government-owned and -operated laboratories to enter into cooperative research agreements with private companies, universities, and others. It also allows private partners to license or take title to Federal inventions in cooperative research and lets the laboratories receive royalties through these agreements (sharing 15 percent or more with employees responsible for invention). Subsequent legislation allowed Federal laboratories to withhold from disclosure certain types of information developed with private sector partners.

The Technology Administration, through its Office of Technology Policy, has taken on

Growth in cooperative R&D between Federal and private sectors



Robert M. White U.S. Department of Commerce

0018-9235/92/$3.00©1992 IEEE

the role of stimulating the transfer process by sponsoring workshops that feature Federal lab research, providing guidance in establishing research agreements, and acting as a broker, or marketing agent, with U.S. industry. The recently announced National Technology Initiative is an example of this type of activity.

'AGILE' MANUFACTURING. In some areas the Commerce Department acts as an *agent for change*. Manufacturing is such a case. As a byproduct of a global economy and the computer age, manufacturing is changing from mass production to what is variously called lean production or agile manufacturing—a process characterized by flexibility, short product cycles, and high-quality output.

Unfortunately, studies indicate that U.S. manufacturers, particularly small and medium-sized enterprises, are slow to adopt this new paradigm. To promote better manufacturing practices, the Technology Administration supports a broad range of programs from research to outreach:

- **Manufacturing research.** To help U.S. industry achieve a paradigm shift in its manufacturing practices, research done in advanced manufacturing technologies by the National Institute of Standards and Technology (NIST) is focused on two efforts. One is supplying the industry with a radically new way of making precisely machined parts with dimensions that can be referenced to national measurement standards maintained by NIST. The other is encouraging the modernization of U.S. manufacturing by providing the technical information necessary to develop standards for measurements, hardware, software, and data interfaces.
- **Manufacturing standards.** A national industry-driven, Government-facilitated effort called the Product Data Exchange coordinates and accelerates a range of standards activities related to the exchange of product data. The use of such standards will allow manufacturers to achieve an open, global, digital product data exchange environment.
- **Quality.** The Malcolm Baldrige National Quality Award is both the U.S. standard of quality achievement and a comprehensive guide to quality improvement in industry. The award program, developed and managed by NIST with the cooperation and financial support of the private sector, recognizes achievements in seven areas of quality management and performance.
- **Outreach.** The Commerce Department's Manufacturing Technology Centers are designed to help small and medium-sized U.S. manufacturers become more competitive. Run by nonprofit organizations and based on modern automated manufacturing techniques, the centers are technology-transfer—rather than research—operations. The centers' approach breaks down the barriers these companies face in adopting new technology by providing up-to-date, practical information and expertise and supporting the implementation of advanced manufacturing technology.

PROMISING TECHNOLOGIES. Emerging technologies—that is, technologies that show promise based on research results but still require significant technical development before they become practical—may represent too high a risk for a corporate investment. A good example is flat panel display technology. While limited work on this technology has been done in the United States, Japan, which has the mechanism for minimizing such risks, has initiated over a dozen commercialization efforts.

> Commerce's role has been to understand innovation as a system and try to make the system work as well as possible

To stimulate U.S. industry to engage in the development of such "precompetitive" technologies, the Commerce Department has established a new program—the Advanced Technology Program—that provides partial funding to either single firms or industry-led joint ventures. The first round of 11 awards was announced last year. Grants were made in such areas as improving manufacturing for electronics, machine tool control, and high-temperature superconductivity.

One of the grants that clearly illustrates the focus of this program is for the development of a holographic memory. Holography and the existence of materials that can be electrically charged by light have been around for some time. The idea of storing information in a holographic pattern in such materials was invented in the early 1960s. To convert this concept into a technology that could compete with semiconductors or magnetic-disk storage requires a good deal of further exploratory work.

This project—submitted by Microelectronics and Computer Technology Corp., Austin, Texas, the microelectronics and computer industry consortium—involves a remarkable degree of vertical integration: Union Carbide for the photorefractive crystals; Texas Instruments, Amoco Laser, and Eastman Kodak for the electro-optic components; Conner Peripherals for the storage system itself; and Cray Research and NCR for the integration of the storage into advanced computers. This is a high-risk project, but it could result in multi-gigabit storage systems with access times 100 to 1000 times faster than conventional storage technology.

One of the Technology Administration's most important roles is to provide the technical infrastructure upon which most of the U.S. economy rests. Central to this function is NIST, which was given a broader mandate by Congress in 1988: "to assist industry in the development of technology. . .needed to improve product quality, to modernize manufacturing processes, to ensure product reliability. . .and to facilitate the rapid commercialization. . .of products based on new scientific discoveries."

The 3000 scientists, engineers, technicians, and support personnel at NIST's laboratories in Gaithersburg, Md., and Boulder, Colo., conduct basic and applied research in the physical sciences and engineering, developing generic technology, measurement techniques, test methods, standards, and related services. The institute also offers more than 300 types of calibration tests, 1000 standard reference materials for calibrating instruments and evaluating testing methods, 24 standard reference data centers, laboratory accreditation programs, and free evaluations of energy-related inventions.

The cornerstone agency for the dissemination of technical, engineering, and business-related information generated by governments worldwide is Commerce's National Technical Information Service, Springfield, Va. It was created in 1945 to collect and declassify World War II technical data. Currently the service is the central source for Federally generated computerized data files, databases, and software. More than 1.5 million of the nearly 2 million reports in the archives are referenced in the service's on-line bibliographic database.

TO PROBE FURTHER. The Commerce Department's Office of Technology Commercialization can provide information on state and local clearinghouses that tap into government technical resources; call 202-377-8100.

The National Institute of Standards and Technology, Gaithersburg, Md., can be reached at 301-975-2300. Its Advanced Technology Program hotline is 301-975-2273, and information on the Product Data Exchange is available at 301-975-3986. The National Technical Information Service, Springfield, Va., can be reached at 703-487-4650.

ABOUT THE AUTHOR. Robert M. White (F) has been the Commerce Department's under secretary for technology since April 1990 and now heads the Technology Administration. He also leads the government-wide Committee on Industry and Technology of the Federal Coordinating Council on Science, Engineering, and Technology. Previously, White was vice president at Microelectronics and Computer Technology Corp., Austin, Texas, where he directed the advanced computing technology program. He was also chief technical officer of Control Data Corp. in Minneapolis, Minn., and principal scientist at Xerox Corp.'s Palo Alto Research Center. His technical specialty is magnetic recording. ◆

HOW ARE WE DOING?

1. I read *IEEE Spectrum*
- ☐ always
- ☐ often
- ☐ sometimes
- ☐ never

2. I find its scope of coverage
- ☐ too narrow
- ☐ just right
- ☐ too broad

3. I find its technical level of presentation
- ☐ too technical
- ☐ just right
- ☐ not technical enough

4. *Spectrum* publishes special issues on one topic or theme. Do you remember these?

Topic	I remember it.	I liked it.
The threat of peace	☐	☐
R&D: managing to be competitive	☐	☐
Europower (EC '92)	☐	☐
Defense: how much is enough?	☐	☐
Engineering careers	☐	☐
AsiaPower	☐	☐
Concurrent engineering	☐	☐
The Gulf (War) legacy	☐	☐

5. I would like to see more (or fewer) of the following types of articles:

	More	Fewer
Advanced technology	☐	☐
Applications	☐	☐
Computers (hardware)	☐	☐
Computers (software)	☐	☐
Communications	☐	☐
Computer-aided design (CAD)	☐	☐
Career development	☐	☐
Management	☐	☐
Power/energy	☐	☐

Other (write in): ______________________

6. I find the illustrations in *Spectrum*
- ☐ excellent
- ☐ good
- ☐ could be improved

7. I find *Spectrum*'s coverage of controversial topics to be
- ☐ objective
- ☐ biased
- ☐ weak

8. The five principal technical areas I would like to see covered in *Spectrum* on a regular basis are

a. ______________________
b. ______________________
c. ______________________
d. ______________________
e. ______________________

9. Specific topics I would like to see covered in the near future are

a. ______________________
b. ______________________
c. ______________________
d. ______________________
e. ______________________

10. My issue is delivered
- ☐ on time
- ☐ late
- ☐ in good condition
- ☐ damaged

11. Lately *Spectrum* has been manufactured without the flat spine, and the money thus saved goes to produce more editorial pages. The lack of a spine
- ☐ is O.K.
- ☐ bothers me

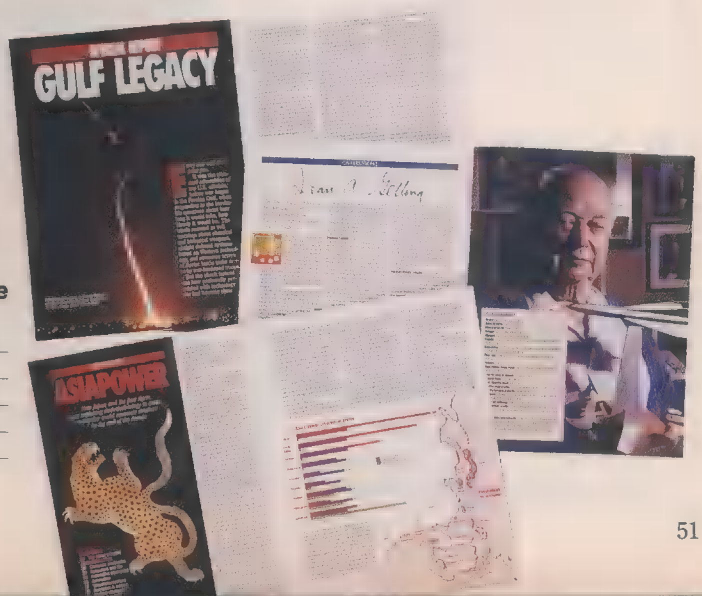
12. Use this space to tell us about changes in content or format you would like us to consider.

____
____
____
____
____
____
____
____

13. I also read THE INSTITUTE (news supplement to *Spectrum*)
- ☐ always
- ☐ often
- ☐ sometimes
- ☐ never

PLEASE SEND YOUR COMPLETED QUESTIONNAIRE OR PHOTOCOPY OF IT TO:

Reader Survey
IEEE Spectrum
345 East 47th St.
New York, N.Y. 10017-2394, U.S.A.



Innovations

Flowering antennas

Antennas fringed with petal shapes may soon be adorning antenna research labs and test ranges if the research of Edward B. Joy, professor of electrical engineering at Georgia Institute of Technology, Atlanta, takes root. Joy discovered that less energy is reflected and scattered at the edge of an antenna if that edge is bordered by petal-shaped serrations some 10 times as deep as the operating wavelength of the antenna.

Petal-fringed antennas are effective over a wide frequency range, can be used in the microwave or millimeter-wave regions, and cost less than rolled antenna edges or subreflectors. The feature benefits radar, compact range antennas, antennas used in earth-to-satellite and satellite-to-earth transmission, and ground-based point-to-point telecommunications.

Joy said he knew from his previous research that serrations around an antenna's edge would reduce reflection and scattering, but he did not know which shape would work best. He and fellow investigators used computer simulations to generate and test triangles and other shapes and combinations of shapes. In one study, antennas with 32 to 128 petals were tested. Various petal lengths and widths were also examined, as well as a random petal root length, the petal length from tip to valley.

Henry Cotten

Most of the work done to date on petal serrations by Joy and his colleagues has been in compact antenna-test ranges. In a compact range, a front-feeding or offset antenna transmits to a point-source parabolic reflector. This, in turn, generates a highly uniform electric field, or quiet zone, used to test the performance of electronic equipment and antennas mounted on trucks, planes, or tanks [see figure].

In computer simulations of compact range reflectors at Georgia Tech, petal serrations were found to trim about 10 dB from the energy reflected into the quiet zone. The length-to-width ratio of each petal may range from 2 to 10. The amount of energy reflected by petal configurations varies little for random or uniform widths of the petals.

The shape of superconductors to come

Superconductors in ingenious configurations discovered at Los Alamos National Laboratory in Los Alamos, N.M., could some day store energy for the electric power industry or contain plasma magnetically in thermonuclear fusion research. A miniature model coil has already been built to test one of the configurations, and researchers hope to receive funding to apply their concepts on a larger scale.

To produce the magnetic fields required to store energy, a large current density is needed. This is achieved when current flows in opposite directions in equally spaced coil conductors arranged either in two concentric circles, or wound around each other as in a helix. These configurations confine the magnetic field to within 100 meters of the storage facility, versus the 16-km extension for older configurations.

There is a tradeoff, though. The nearness of conductors in these configurations to each other also reduces their capacity for storing energy by some 30 percent (exactly how much depends on the distance between conductors). U.S. patent 5 006 672 for various configurations was granted to Melvin L. Prueitt, Fred M. Mueller, and James L. Smith of Los Alamos National Laboratory, Los Alamos, N.M., on April 9, 1991.

For plasma confinement, parallel wires running along the perimeter of a vacuum chamber are reorganized—alternate wires are moved a little toward the center of the chamber. The current in these wires is less than, and flows in the opposite direction to, the current in the outer wires. At a certain ratio of radii and a certain ratio of current, the forces on the wires become zero. At a distance, magnetic fields cancel each other.

Wires in this configuration can generate extremely strong magnetic fields of up to 100 teslas, which are ideal for plasma confinement, according to Prueitt. For this discov-

(Continued on p. 53)

PRODUCT PROFILES

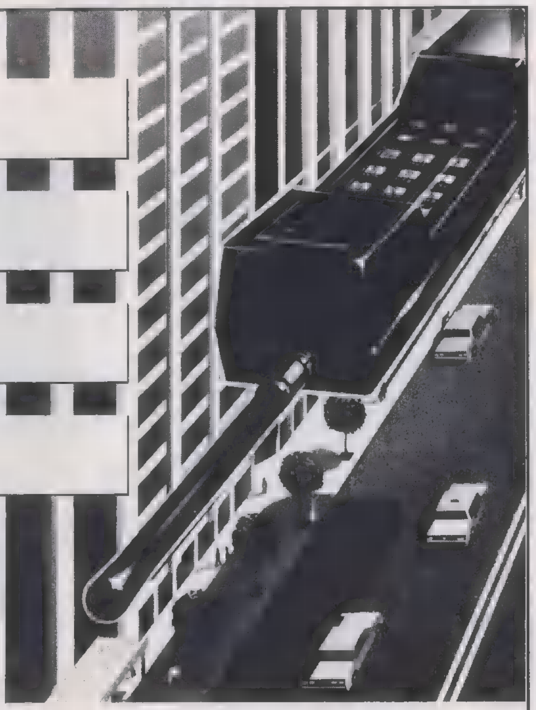
The PRODUCT PROFILES advertising section provides a distinctive focus on both new and commercially established products and services that offer practical solutions for engineering and scientific professionals in today's fast-paced, rapidly changing high-tech environment.

Employment opportunities

Organizations seeking engineers and scientists describe their various openings in the following advertising section

In order to conform to the Age Discrimination in Employment Act and to discourage age discrimination, IEEE may reject any advertisement containing any of these phrases or similar ones, "recent college grads," "1–4 years maximum experience," "up to 5 years experience," or "10 years maximum experience." IEEE reserves the right to append to any advertisement, without specific notice to the advertiser, "Experience ranges are suggested minimum requirements, not maximums." IEEE assumes that, since advertisers have been notified of this policy in advance, they agree that any experience requirements, whether stated as ranges or otherwise, will be construed by the reader as minimum requirements only. While IEEE does not ban the use of the term "entry level," its use is discouraged since, to some, it connotes an age rather than an experience designation. IEEE accepts employment advertising to apprise its members of opportunities. Interested parties should be aware that the political and humanistic values of certain advertisers may differ from their own. IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

We're bringing opportunity to San Diego.



From Finland comes NOKIA Mobile Phones, Europe's largest — and the world's second largest mobile phone manufacturer. As part of the NOKIA group of high-technology companies with research and development centers worldwide, we are expanding to the U.S. and have selected San Diego as the site for our latest R&D Center. Currently, we are seeking self-directed engineers to be the innovators of future generations of NOKIA hand-held portable digital cellular phones.

As a NOKIA engineer, you will benefit from our progressive management style, which supports concurrent engineering while making us a Six Sigma TQM Company. Unstructured, yet strategically focused, our new R&D Center in San Diego will be a magnet for engineers seeking the stability, resources, state-of-the-art development tools and vision only a company of NOKIA's global stature can provide.

Start from the future by investigating the following opportunities:

- **TELECOM FIRMWARE DEVELOPMENT ENGINEER**
- **HARDWARE DESIGN ENGINEERS**
- **ASIC DESIGN ENGINEERS**
- **RF/IC DESIGN ENGINEERS**
- **PRINCIPAL SYSTEM ENGINEER**
- **DSP SYSTEMS ENGINEER**

Discover the proven product lines and exciting opportunities that NOKIA is bringing to San Diego by sending your resume, referencing position for which you are applying, to: NOKIA Mobile Phones, Code 101, 9605 Scranton Rd., #303, San Diego, CA 92121.

NOKIA
Equal opportunity employer

CLASSIFIED

ADVERTISING RATES
DISPLAY ADVERTISING RATES—call *Spectrum* at 212-705-7579
CLASSIFIED
Positions open—$36.00 per line, not agency-commissionable
Positions wanted—$36.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy

All classified advertising copy must be received by the 25th of month, two months preceding date of issue. No telephone orders accepted. For further information contact Theresa Fitzpatrick, 212-705-7578.

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

Academic Positions Open

University of Illinois at Chicago. Instructorships and tenure-track faculty positions in electrical engineering and computer science at both the junior and senior level are available. Rank and salary commensurate with qualifications. An earned Doctorate in EE or CS must be completed by date of appointment, but not for the instructorships. Demonstrated teaching and research abilities are highly desirable. For full consideration, please send resume, list of publications, and the names of at least three references by April 30, 1992 to Dr. Wai-Kai Chen, Head, Department of Electrical Engineering and Computer Science (M/G 154), University of Illinois at Chicago, P.O. Box 4348, Chicago, IL 60680. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

The UCLA Department of Mechanical, Aerospace, and Nuclear Engineering invites applications for a faculty position in plasma physics. Candidates will be considered at the Assistant Professor or Full Professor level. Preferably, the department is seeking a distinguished, well established scholar who has done research in the area of theoretical plasma physics with an emphasis on problems important to magnetic fusion research. Experience and interest in the use of advanced computational methods is desirable in order to augment existing strengths at UCLA in computational fluid dynamics and plasma simulations. The candidate should be highly motivated to enhance our graduate research program in fusion, to interact with other faculty and staff in the department and in the Institute of Plasma and Fusion Research at UCLA, and to interact with individu-

CLASSIFIED

als at government research center and industry who are at the forefront of fusion plasma physics research. It is expected that the candidate would establish and lead a major research activity. Salary and appointment level will be commensurate with experience and qualifications. Candidates should submit a letter of application, a complete resume, and the names of five references to: Prof. Robert W. Conn, Chairman of Search Committee, Department of Mechanical, Aerospace and Nuclear Engineering, 44-139 Engineering IV, 405 Hilgard Avenue, University of California, Los Angeles, Los Angeles, CA 90024-1597.

The University of Texas at Austin, Department of Electrical and Computer Engineering is accepting applications for tenure track assistant professor positions. Resumes will be considered in the following areas: 1) Software Engineering 2) Telecommunications Engineering, including microwave engineering; image and signal processing 3) Manufacturing Systems Engineering, and 4) Optical Interconnect Technology. Applicants should send resume and the names and addresses of at least three references to Dr. Mario J. Gonzalez, Chairman, Department of Electrical and Computer Engineering, The University of Texas at Austin, Austin, TX 78712-1084. The University of Texas at Austin is an Equal Opportunity/Affirmative Action Employer.

The Microwave Remote Sensing Laboratory (MIRSL) of the University of Massachusetts is seeking highly-qualified Ph.D. candidates interested in exciting research opportunities in sensing geophysical phenomena. MIRSL specializes in developing microwave and millimeter-wave sensing instruments for ground-based and airborne experiments and in the analysis of data measured with these sensors. Research is currently underway to remotely sense ocean surface winds, currents, salinity, temperature, and sea ice; atmospheric water vapor, turbulence, cloud dynamics, and precipitation; and foliated and snow-covered terrain. We seek students who wish to be involved in all aspects of our research, including problem identification, instrument development, field experiments, and data analysis. Appropriate candidates will have earned bachelor's degree with distinction in Electrical Engineering or Physics. Research assistantship stipends begin at $12,500/year. A limited number of fellowships at $16,000/year are also available. Applications will be accepted until suitable candidates have been identified. For more information, please contact Dr. James Mead, Room 113B, Knowles Engineering Building, University of Massachusetts, Amherst, MA 01003; phone (413) 545-2463. The University of Massachusetts is an Affirmative Action/Equal Opportunity Employer and encourages women and minorities to apply.

The University of Cincinnati—The NASA Space Engineering Research Center and the Department of Electrical and Computer Engineering invite applications for new tenure-track faculty positions at the Assistant/Associate Professor levels starting January 1992. The primary areas of interest are solid state electronics with an emphasis on microelectronics-based sensors, micromechanical structures, microstructures, chemical or RIE micromachining, analog and digital electronics circuit design for smart sensing, electronic instrumentation and non-intrusive diagnostics using microsensors for space engineering. The Department offers B.S., M.S., and Ph.D. programs in Electrical and Computer Engineering. The Department has 30 full-time faculty, 160 full-time graduate students, 400 undergraduate students, 2 research centers, and 20 full-time staff members, and graduates approximately 35 M.S. and 15 Ph.D.'s per year. Externally funded research is currently at $4.0M per year and growing. The University is supportive of the Department in providing an environment conducive to the establishment of an academic and professional career. The Space Engineering Research Center is one of nine national research centers sponsored by NASA. It currently supports multi-disciplinary research and educational programs involving faculty and students in the College of Engineering. The successful candidate will hold a regular full-time faculty rank in the Department of Electrical and Computer Engineering with a joint appointment at the NASA Space Engineering Center. He/she is expected to play a leading role in the development of a collaborative research and educational program between the Space Research Center and the Department in microsensors and instrumentation. All candidates should have a strong commitment to excellence in research and teaching and an earned Ph.D. in electrical engineering. Please send curriculum vitae to: Dr. Vik J. Kapoor, Head, Electrical and Computer Engineering Department, University of Cincinnati, Cincinnati, Ohio 45221-0030. E-mail vkapoor@uceng.uc.edu. The University of Cincinnati is an Affirmative Action/Equal Opportunity employer and encourages and welcomes applications from women and minorities.

University of Illinois at Urbana-Champaign. The Department of Electrical and Computer Engineering invites applications for several tenure track and tenured faculty positions. Applicants must have an earned Ph.D., outstanding academic credentials, and an ability to teach effectively at both the graduate and undergraduate levels. Selected candidates will be expected to initiate and carry out independent research and to perform academic duties associated with our B.S., M.S., and Ph.D. programs. The department has one of the largest programs in the United States granting approximately 400 B.S., 100 M.S. degrees and 65 Ph.D. degrees. Research is conducted in acoustics, bioengineering, communications, computer engineering, computer vision & robotics, control, electromagnetics, integrated circuits, laser and electro-optics, microelectronics, power systems and power electronics, signal processing, and remote sensing. Particular need exists for faculty in communication systems. However, all candidates judged to have outstanding qualifications for a position in any of the above areas will be interviewed. The University of Illinois is an equal opportunity/affirmative action employer. Send resume, with references and a list of publications, to: Faculty Search Committee, Department of Electrical and Computer Engineering, 1406 West Green Street, University of Illinois, Urbana, IL 61801.

Southern Methodist University, Computer Science and Engineering—The Department of Computer Science and Engineering (CSE) invites applications for a junior faculty position in Computer Engineering at the Assistant Professor level. Applicants must have a Ph.D. in Computer Engineering, Computer Science, or a related discipline. It is anticipated that the position will be filled by August, 1992. SMU is a private university with approximately 8,000 students. The Department of Computer Science and Engineering is in the School of Engineering and Applied Science, where a close working relationship exists with the Departments of Electrical Engineering and Mechanical Engineering. The CSE Department presents a balanced program of research and education at all levels and has been offering Ph.D. degrees since 1970. The Department has extensive contacts with computer-related and engineering-oriented industrial firms that distinguish Dallas as one of the top centers for high technology. Applicants should send a complete resume, including the names of at least three references to: Professor Margaret H. Eich, Chair, Faculty Search Committee, Department of Computer Science and Engineering, Southern Methodist University, Dallas, Texas 75275-0122. SMU is an equal opportunity/affirmative action, Title IX employer. Applications from women and minorities are particularly encouraged. Applications will be accepted until April 15, 1992.

Wright State University, Department of Computer Science and Engineering invites applicants for tenure-track faculty positions at all ranks. The successful candidate should have a Ph.D. in computer science, computer engineering, or equivalent degree, and have demonstrated forward looking and creative research as evidenced by recent journal publications. Further desired attributes include: capability to direct Ph.D candidates and/or direct research projects. Preferred technical areas are distributed systems, networking, parallel computing, and

ISSA/NSA POLY

USE YOUR "TICKETS" FOR FASTER CAREER GROWTH

Put our 25+ years experience placing technical professionals to work for you. All fees paid. Nationwide opportunities in Communications, Defense, Intelligence, Computer, Satellites and Analytical Sciences. If you earn over $35,000, we have a better, more rewarding job for you ... right now. U.S. citizenship and ISSA/NSA POLY desirable. Call (301) 231-9000 or send your resume in confidence to: Dept. EA-I3EB or FAX to: (301) 770-9015.

WALLACH
associates, inc.
Technical and Exec[illegible]

Washington Science Center
6101 Executive Boulevard
Box 6016
Rockville, Maryland 20849-6016

UNIVERSITY OF HONG KONG
FACULTY OF ENGINEERING

Reader/Senior Lecturers/Lecturers in the Department of Electrical and Electronic Engineering
(Ref. RF/TA/Engg/5)

Applicants should possess a higher degree, preferably a PhD or its equivalent, and have a proven record of research in one of the following areas: VLSI design, data communications, telecommunications, robot control and vision, energy systems and electric vehicles. Preference will be given to those having substantial teaching or relevant experience in microprocessors, computer systems, analogue electronics, and energy technology.

Salary per annum (superannuable) is on the following scales:

Reader (R)	HK$501,120–665,700 (9 points) (US$64,861–US$86,164)
Senior Lecturer (SL)	HK$480,360–645,300 (9 points) (US$62,175–US$83,522)
Lecturer (L)	HK$309,120–516,480 (11 points) (US$40,010–US$66,850)

US Dollar equivalents are at 14 January 1992. Starting salaries depend on qualifications and experience. At current rates, salaries tax will not exceed 15% of gross income. Children's education allowances, leave and medical benefits are provided; housing or tenancy allowances are also provided in most cases at a charge of 7.5% of salary.

Further particulars and application forms may be obtained from Appointments (40263), Association of Commonwealth Universities, 36 Gordon Square, London WC1H OPF, UK; or from the Secretary, Faculty of Engineering, University of Hong Kong, Hong Kong (Fax (852) 5469142, E-mail HUUR-ENG@HKUVM.BITNET).

Closes: *31 March 1992.*

database, but other areas will be considered. The university is located in a high technology environment among industrial/military research and development facilities, including Wright Patterson Air Force Base and NCR. Department strengths include a fully networked Unix environment of Sun & DEC workstations; Cray access; and graduate laboratories in AI, optical computing, neural networks, and robotics; degree programs in both computer science and computer engineering; and approximately 150 selected graduate students. The department has 25 faculty, four of whom were awarded NSF research initiation awards last year. Please submit a detailed resume including names of three references to: CSNET address—amcaulay@cs.wright.edu or Alastair D. McAulay, NCR Distinguished Professor and Chair, Department of Computer Science and Engineering, Wright State University, Dayton, Ohio 45435. Pending availability of funding, reviewing for positions will begin February 15, 1992 and continue monthly until positions are filled or until September 1, 1992. An Equal Opportunity/Affirmative Action Employer.

The University of Calgary, Academic Positions, Department of Electrical and Computer Engineering—The University of Calgary Department of Electrical and Computer Engineering invites applications for two full-time tenure-track academic positions at the Assistant or Associate Professor rank effective July 1, 1992. Requirements include a PhD and significant expertise in Electrical and Computer Engineering, especially in one or more of: electronics, VLSI circuits, power systems, power electronics, computer engineering. Strong computing background essential. Excellent computing facilities and specialized facilities are available to pursue teaching and research. Candidates must develop an active research program, teach at undergraduate and graduate levels, and supervise graduate students. Salary commensurate with qualifications and experience. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. The University of Calgary has an Employment Equity Program and encourages applications from all qualified candidates, including women, aboriginal people, visible minorities and people with disabilities. The University offers a Dual Career Assistance Program for spouses. Send applications, with a curriculum vitae and the names of three references, by March 31, 1992 to: Head, Department of Electrical and Computer Engineering, The University of Calgary, 2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4.

Faculty Position—Assistant Professor (Tenure Track), Electrical Engineering, The Division of Engineering, The University of Texas at San Antonio. The Division of Engineering at the University of Texas at San Antonio invites applications for a tenure-track Assistant Professor position in Electrical Engineering. Ph.D. degree required. Successful candidates are expected to participate in both undergraduate and graduate teaching, and in research activities. Applicants in all areas of electrical engineering are invited to apply, but the following areas are of special interest: communications; computer engineering with emphasis on distributed and parallel processing and fault tolerant computing; digital signal processing; solid state devices; digital systems or microelectronics; and VLSI. Salary commensurate with qualifications and experience. UTSA is a comprehensive metropolitan university located on the edge of the Texas Hill Country. San Antonio combines a rich cultural heritage with a modern focus on education, research, and technology. Send resume and names, addresses, and phone numbers of four references by April 6, 1992 to: Chair, Electrical Engineering Search Committee, Division of Engineering, The University of Texas at San Antonio, San Antonio, Texas 78249-0665. UTSA is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

North Carolina State University. The Department of Electrical and Computer Engineering has a limited number of openings for Visiting Assistant Professors and tenure-track Assistant Professors. Visiting Assistant Professors are appointed for fixed non-renewable terms of one or two years. Tenure-track Assistant Professors are appointed for a first term of four years with possibility of renewal for a second three-year term. Qualifications for Assistant Professors include a doctorate in electrical engineering, computer engineering, or closely related discipline; a commitment to excellence in research and teaching; and a demonstrated ability for scholarly work. Applications for Instructors and Lecturers will also be considered. Qualifications for Instructors and Lecturers include significant industrial or governmental R&D experience; an advanced degree in electrical engineering, computer engineering, or computer science; and a commitment to excellence in teaching. Opportunities for employment exist or may exist in a number of areas, including computer architecture, electric power systems, robotics and intelligent machines, optoelectronics, VLSI design, solid-state electronics, computer communications, and signal processing. The department offers programs leading to BS, MS, and PhD degrees in electrical and computer engineering. The department has approximately 50 full-time, tenure-track faculty members, 1200 undergraduate students, 400 graduate students, and annual research expenditures of approximately 50 full-time, tenure-track faculty members, 1200 undergraduate students, 400 graduate students, and annual research expenditures of approximately $8,000,000. Research activities are concentrated (administratively) in the following organized research units: The Center for Communications and Signal Processing, the Computer Systems Laboratory (joint with Computer Science), the Electrical Power Research Center (joint with Nuclear Engineering), The Engineering Research Center for Advanced Electronic Materials Processing, the Solid-State Laboratories, the High Frequency Electronics Laboratory, the Power Semiconductor Research Center, and the Robotics and Intelligent Machines Laboratory. The department and organized research units enjoy support and close cooperation with industrial firms and research laboratories in the Research Triangle Park and elsewhere. Inquiries should be sent to R.K. Cavin, III; Department of Electrical and Computer Engineering, Box 7911; North Carolina State University; Raleigh, NC 27695-7911. North Carolina State University is an equal-opportunity, affirmative-action employer.

University of Idaho, Department of Electrical Engineering, invites applications for a faculty position at the assistant professor level with a specialty in computer engineering, digital systems, control systems, electromagnetics, power, or analog electronics. The current vacancy is at the Idaho Falls Center for Higher Education, a branch campus in Idaho Falls, ID. Duties include teaching at the graduate and undergraduate levels, research in the specialty area, and contributing to the academic program in the department. Preliminary selection qualifications are an earned PhD in electrical/computer engineering or a closely related field, specialization in computer engineering, digital systems, control systems, electromagnetics, power, or analog electronics, and US citizenship or permanent residency. Intermediate selection qualifications include effective communication skills, teaching ability, research ability, professional compatibility with department goals, and industrial experience. The Department offers the BS, MS, M. Engr., and PhD degrees in electrical engineering and the BS, MS, and M. Engr. degrees in computer engineering. The University of Idaho has statewide responsibility for engineering education, is a land-grant university with about 9,000 students, and is located in northern Idaho approximately 10 miles from Washington State University. Research activity includes the Microelectronics Research Center (MRC), specializing in VLSI design; the MRC receives NASA support as one of nine original Space Engineering Research Centers. Idaho Falls is located in southeast Idaho in the center of renowned recreation areas. The Idaho Falls Center works closely with the Idaho National Engineering Laboratory in its research and educational programs. Search and selection procedures will be closed when a sufficient number of qualified applicants has been identified, but not earlier than April 1, 1992. Send letter, resume, names of three references, and statement of residency status to Dr. John Law, Department of Electrical Engineering, University of Idaho, Moscow, ID 83843-4199. The University of Idaho is an EO/AA employer.

The Electrical Engineering Technology Department of Purdue University announces anticipated academic-year tenure-track positions in West Lafayette, Anderson, Columbus, Kokomo, New Albany, and South Bend, Indiana, commencing August 17, 1992. Minimum requirements are: three years of recent relevant industrial experience; a strong commitment to undergraduate teaching; a master's degree in electrical engineering technology, electrical engineering, or a closely related field. Applicants must have expertise in at least two specialty areas. Candidates from industry, engineering technology programs, or strong community college technical programs are encouraged to apply. In addition to teaching, faculty will be expected to engage in curriculum development, some program coordination, student advising, take an active role on department or university committees, and to pursue scholarly activity by publishing and participating in professional society meetings. For priority consideration, applications should be submitted by April 3, 1992. However, the positions will remain open until they are filled. Send a detailed resume, the names, addresses and phone numbers of three references, and your location preference(s) to the: EET Faculty Search Committee, Electrical Engineering Technology Department, Knoy Hall, Purdue University, West Lafayette, IN 47907. Purdue is an equal opportunity/affirmative action employer.

Electrical Engineering: Department of Electrical Engineering of Northern Illinois University, invites applications for tenure-track Assistant or Associate professor positions for Fall 1992 semester with demonstrated experience in several of the following specialty areas: semiconductor device fabrication, micro-machining, micro-sensor fabrication, data communication, analog communications, microwave devices, fiber-optics, electromagnetics and materials. Preference will be given to those applicants who have demonstrated significant academic experience, record of teaching and research, and scholarly publications. Earned doctorate in Electrical Engineering and U.S. citizenship or permanent U.S. residency is required. Salary, rank, and tenure status will be commensurate with qualifications and accomplishments. Applications must be received by April 1, 1992. Clearly identify the particular specialization in your letter of application. Send letter of application, resume, names of three references and samples of recent publications to Professor Alan P. Genis, Chair, Department of Electrical Engineering, Northern Illinois University, DeKalb, IL 60115-2854. Northern Illinois University is an equal opportunity, affirmative action employer. We sincerely urge native Americans, African Americans, Hispanic Americans and women to apply. The college is strongly committed to the cultural, ethnic, and gender diversification of its faculty.

Research Assistant Professor in the Medical Imaging Research Laboratory at the University of Utah. The Department of Radiology invites applications for a nontenure-track position at the research assistant professor level to work in the Medical Imaging Research Laboratory. The applicant should have a Ph.D. in either physics, electrical engineering, biophysics, or applied mathematics. The successful candidate will be expected to participate in single photon emission computed tomography (SPECT) research which includes the development of cone beam tomography both for the data sufficiency and the data insufficiency case, the improvement of iterative reconstruction algorithms which include better models of the physics of the imaging detection process, and the development of kinetic models which are able to measure in vivo cardiac and brain physiology using dynamic SPECT acquisition. An understanding of x-ray imaging, magnetic resonance imaging and other imaging tech-

Here's your chance to plot a course into the most selective Nuclear Engineering Program in the nation. And in doing so, you can earn over $25,000 while you complete your college education.

Nowhere else can you get such extensive hands-on nuclear experience as in the Navy's submarines.

Qualify as a Navy Nuclear Propulsion Officer Candidate, and you'll receive over $1,000/month during your junior and senior years. In addition, the Navy will pay you $4,000 when you enter the program and $2,000 upon its successful completion.

Belonging to the Navy Nuclear Engineering Program means being among the smartest and brightest in the engineering field.

But more importantly, you'll be working on the most state-of-the-art equipment in the nuclear field today. Aboard the most sophisticated ships in the world: Navy aircraft carriers, submarines and cruisers.

Talk to a Navy Programs Officer today. Or call 1-800-327-NAVY. Then get ready to become a force in your field. Because in today's high-tech Navy, you only go one way: Full speed ahead.

NAVY

**YOU AND THE NAVY.
FULL SPEED AHEAD.**

niques are required so that the candidate filling this position can give lectures and teach laboratory classes in medical imaging. The medical imaging research laboratory has three faculty members, two postdoctoral research associates, and fifteen graduate students working on research projects in x-ray imaging, x-ray computed tomography, laser mammography, single photon emission computed tomography, MR angiography, and MR spectroscopy. The laboratory has access to three-decector, two-detector, and one-detector SPECT systems. In addition, there is access to SUN work stations, an IBM supercomputer, and Stardent 750 and 1500 computers. The applicant should send a resume and three letters of recommendation to: Grant T. Gullberg, Ph.D., Department of Radiology, Medical Imaging Research Laboratory, AC215 Medical Center, University of Utah, Salt Lake City, Utah 84132. Deadline date: April 1, 1992 or until suitable candidate is identified. EEO/AA Employer.

Tenure-Track Faculty Position in the Medical Imaging Research Laboratory at the University of Utah. The Department of Radiology invites applications for a tenure-track position at the associate or full professor level to work in the Medical Imaging Research Laboratory. The applicant should have a Ph.D. in either physics, electrical engineering, biophysics, or applied mathematics. The successful candidate will be expected to develop a research program in magnetic resonance imaging (MRI) and to teach courses in medical imaging. Of particular interest to the department is research in MRI which will lead to enhancing MR angiography, to understanding the homodynamics of blood flow during MRI data acquisition, and to improving methods for measuring tissue perfusion. Presently, the Medical Imaging Research Laboratory has three faculty members, two postdoctoral research associates, and fifteen graduate students from physics, electrical engineering, bioengineering, and biophysics. The laboratory has research projects in x-ray imaging, x-ray computed tomography, laser mammography, single photon emission computed tomography, MR angiography, and MR spectroscopy. The laboratory has access to large bore human MRI and small bore animal systems, SUN work stations, IBM supercomputer, and Stardent computers. The applicant should send a resume and three letters of recommendation to: Grant T. Gullberg, Ph.D., Department of Radiology, Medical Imaging Research Laboratory, AC215 Medical Center, University of Utah, Salt Lake City, Utah 84132. Deadline date: April 1, 1992 or until suitable candidate is identified. EEO/AA Employer.

Electrical Engineering: Tenure track faculty position available at the Assistant, Associate, or Full Professor level in the Electrical Engineering Department, South Dakota School of Mines and Technology. Primary need is for applicants with specialization in the areas of Computer Engineering or Digital Systems but all specialities will be considered. Responsibilities will include both teaching and research. Applicants must possess a doctoral degree in Electrical or Computer Engineering or be scheduled to complete all degree requirements by September 1, 1992. Salary is commensurate with qualifications and experience. South Dakota School of Mines and Technology, founded in 1885, has an enrollment of approximately 2,500 students and offers degrees in all the major branches of engineering and the physical sciences. The school is located in Rapid City, the second largest city in South Dakota, and the gateway to the Black Hills of western South Dakota. Applications, including a resume, a statement of teaching and research interest, and names and addresses of at least three references should be sent to: Professor Richard D. McNeil, Chairman, Electrical Engineering Faculty Search Committee, Electrical Engineering Department, South Dakota School of Mines and Technology, 501 East St. Joseph Street, Rapid City, SD 57701-3995. Phone (605) 394-2451. Applications are desired before April 15, 1992, but the search will remain open until the position is filled. South Dakota School of Mines and Technology is an equal opportunity, affirmative action employer, and encourages applications from qualified women and minorities.

Research Associate: Electrical Engineering-Systems. Conduct research in VLSI design. Develop a knowledge-based system for the design of testable digital circuits. Prepare and design reports for users manual and for research publications. Req: Ph.D. in Computer or Electrical Engineering. 2 yrs. experience in VLSI Design. Specialized knowledge of ATPG, BIST, DFT and fault tolerant designs. Background in software engineering, CAD object oriented database. Knowledge and ability to use C, C++, Pascal, Lisp, Prolog, Unix, V-base, X-windows, Sun workstations, Ethernet/LAN protocol. Sal. $923.07/wk; 40 hrs/wk. Job/Interview site: Los Angeles, CA. Send this ad and a resume to Job #LG1212, P.O. Box 9560, Sacramento, CA 95823-0560 no later than 4/1/92.

Princeton University: the department of Electrical Engineering invites applications for full time, tenure-track faculty position. The disciplines of particular interest are complex systems, specializing in areas such as robotics, manufacturing systems, networks, and stochastic or nonlinear systems; and signal processing, specializing in areas such as video and image processing. Please send a complete resume, a description of research and teaching interests, and names of three references to Professor Stuart Schwartz, Chair, Dept. of EE, Princeton University, Princeton, NJ 08544-5263. Princeton University is an equal opportunity/affirmative action employer.

Stanford University Center for Telecommunica-

AUBURN UNIVERSITY
SPACE POWER INSTITUTE

POSTDOCTORAL FELLOW, RESEARCH ASSISTANT/ASSOCIATE & JUNIOR ENGINEER POSITIONS AVAILABLE - ALL DISCIPLINES
Next 18 Months

Auburn University is seeking several candidates for a variety of non-tenure track Postdoctoral Fellow, Research Assistant and Associate, and Junior Engineer positions to begin on or about March 15th, 1992. Applicants should have a BS, MS or PhD degree in one of the following areas: satellite communications, K_a band propagation, orbital debris, arc drives, space power, space environmental effects, electrochemistry / electrochemical engineering, surface science / surface chemistry, tribology / surface studies, heterogeneous catalysis / surface chemistry,diamond film deposition, solidification, crystal growth, biotechnology / biochemical engineering, energy storage devices / chemical double layer capacitors, solid state physics, high temperature materials / electronics, physical chemistry. Applicant's vitae should show experience in experimental research with knowledge of technology transfer opportunities and commercial applications. Position appointments will be for one year, but renewable, dependent upon mutual consent and availability of research funds. Salary will be based upon academic credentials and experience. This notice is valid for 18 months, and all applications received will be retained and considered for all new positions throughout this period. Applicants should send vitae with statement of specific research interests, three letters of reference, reprints, preprints to Dr. M. Frank Rose, Space Power Institute, 231 Leach Center, Auburn University, AL. 36849-5320.

Auburn University is an Affirmative Action/Equal Opportunity Employer, and an Equal Opportunity Educational Institution. Minorities and Women are encouraged to apply

Princeton University
Department of Electrical Engineering
POEM/ATC MANAGER

The Department of Electrical Engineering seeks application for the position of Manager for the Photonic Opto-Electronic Material (POEM) Advanced Technology Center (ATC). The POEM ATC is an interdisciplinary research and educational activity centered in the Electrical Engineering Department. POEM is sponsored by the N.J. Commission on Science and Technology.

The Manager will be responsible for supervising the technical and office staff, coordinating educational and technology transfer programs, acting as liaison with other New Jersey higher educational institutions and industries and serving as the executive assistant to the faculty director of the Princeton POEM. Previous experience should include work in a technical environment and the individual should have demonstrated administrative ability.

Application deadline March, 31, 1992. Send 2 copies of resume to: DJ, Office of Human Resources, Princeton University, Clio Hall, Princeton, NJ 08544.

Princeton University
Equal Opportunity /Affirmative Action Employer

tions Professor (Research) and Executive Director. Stanford University seeks applications for a position Professor (Research) in Electrical Engineering and Executive Director of the Center for Telecommunications. Candidates must have ■ proven track record of research in the telecommunications field, and should have an understanding of future trends in the communications industry. A Ph.D. and prior industrial experience in this field are necessary, but an ability to work in the academic environment with multiple faculty from multiple disciplines is also required. The successful candidate will be expected to supervise the research of Ph.D. students, and will also serve as the primary interface to industrial Members of the Center. Membership recruitment and associated fund raising will be an important part of the responsibilities. This is a non-tenure-track position, with no teaching duties, and with funding supplied by the Center for Telecommunications. The Center involves about 15 faculty members from the Departments of Electrical Engineering, Computer Science and Engineering Economic Systems and approximately 10 industrial firms from around the world. A central theme of the Center is personal communications, interpreted in a broad sense. Stanford University is an Equal Opportunity Employer, and encourages applications from women and minority candidates. The deadline for receipt of applications is April 30, 1992. Applications should be sent to Prof. Leonid Kazovsky, Chairman of the Search Committee, Department of Electrical Engineering, Durand 202, Stanford University, Stanford, CA 94305.

Dean of Engineering Michigan Technological University. Michigan Technological University invites applications and nominations for the position of Dean of the College of Engineering. The Dean reports directly to the Provost and is expected to provide leadership in undergraduate and graduate education and research. MTU is one of the largest undergraduate engineering institutions in the country and houses growing graduate programs. The College of Engineering is the largest academic unit of the University. It has approximately 4400 undergraduate, 225 M.S., and 130 Ph.D. students and 150 faculty in the departments of Chemistry, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering, General Engineering, Geological Engineering, Geology and Geophysics, Mechanical Engineering, Metallurgical and Materials Engineering, and Mining Engineering. Qualifications include an earned doctorate, ■ distinguished research and teaching record appropriate for a tenured appointment in the College, proven leadership and administrative ability, and ■ demonstrated commitment to affirmative action and diversity. Nominations and applications, including resume and names, addresses, and phone numbers of three references, can be sent to Dr. Martha Sloan, Chair, Dean of Engineering Search Committee, Office of the Provost and Vice President for Academic Affairs, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931. The position is open 1 September 1992. Applications will be reviewed continuously until the position is filled. Michigan Technological University is an equal opportunity educational institution/equal opportunity employer.

Electrical/Computer Faculty Positions. The Department of Electrical and Computer Engineering at LSU invites applications for anticipated tenure-track and visiting faculty positions at the assistant, associate and full professor levels available August 1992 in the following areas: electric energy systems, including power electronics; solid state electronics; systems, including automatic control, communications and signal processing; and computers, including microprocessors, distributed processing systems and special purpose architectures. A PhD or equivalent degree and potential for excellence in teaching and research are necessary. The positions involve teaching graduate and undergraduate courses in electrical and/or computer engineering and research in areas of individual interest. Completion of all PhD requirements is necessary before employment begins. Salary is competitive and commensurate with qualifications and experience. Release time and resources are provided in order to enhance the development of ■ quality research program. Opportunities for summer support are available. Send resume, names of three references, a statement of teaching and research interests, and verification of employment eligibility in compliance with the Immigration Reform and Control Act of 1986 to: Alan H. Marshak, Chairman, Electrical and Computer Engineering, Louisiana State University, Baton Rouge, LA 70803-5901. LSU is an Equal Opportunity Employer.

Faculty Positions in Robotics—Carnegie Mellon University Robotics Ph.D. Program. Applications are invited for tenure-track faculty positions in the Robotics Ph.D. Program at Carnegie Mellon University. Appointees are expected to play major roles in education and research in the program. Appointments are expected to be at the assistant professor level in the Robotics Ph.D. Program, although joint appointments with other departments or non-tenure-track research appointments could also be considered. Applicants must have a Ph.D. in ■ related discipline and have demonstrated competence in one or more areas of robotics research, as well as potential for excellent teaching. Outstanding candidates in all areas of robotics are invited, including, but not limited to, mechanisms, manipulation, sensors, control, locomotion, vision, design, planning, knowledge-based systems, simulation, graphics, micro-electronics, parallel computing, manufacturing, and management. Applicants should send their applications with curriculum vitae and names of at least four references to: Chair, Faculty Search Committee, The Robotics Institute, Carnegie Mellon University, Pittsburgh, PA 15213-3890, Attn: Nancy Serviou. Carnegie Mellon is an Equal Opportunity/Affirmative Action employer.

Drexel University. The Department of Electrical Engineering and Computer Engineering expects to have tenure-track and visiting faculty positions for the academic year 1992-1993. At the present time we are seeking individuals with strong interest in engineering education and academic research, whose areas of specialization are in the general area of communications, telecommunications, mobile communications, and networking. Applicants must have ■ Ph.D. The ECE Department has active groups in the areas of System Theory, Computer Engineering, Power Systems and Electrophysics. Send Curriculum Vitae, including the names of five references, to: Dr. Bruce A. Eisenstein, Head, Department of Electrical and Computer Engineering, Drexel University, Philadelphia, PA 19104. Immigration status of non-US citizens should be stated. Drexel University is an equal opportunity/affirmative action employer, and welcomes applications from women and minorities.

The George Washington University Visiting Professorships Research Faculty/Research Staff. Visiting Professorships, Research Faculty, and Research Staff Positions, at junior and senior levels, are available in the School of Engineering and Applied Science. The George Washington University starting Fall Semester 1992. The School of Engineering and Applied Science is organized into four academic departments: The Department of Civil, Mechanical and Environmental Engineering; the Department of Electrical Engineering and Computer Science; the Department of Engineering Management; and the Department of Operations Research. Candidates are especially sought to teach and/or conduct research in the following areas: Artificial Intelligence; Communications; Computer Graphics; Computer-Integrated Design and Manufacturing; Computer Science; Computer Security; Data Networks; Decision Support Systems; Energy Management; Engineering Management; Information Technology Management; Integer and Network Programming; Manufacturing/Production Management; Mathematical Optimization; Mechanical Engineering Design; Operations Research; Project and Program Management and Total Quality Management; Reliability; Simulation; Software Engineering; Stochastic Processes; Structural Engineering; Systems Engineering; Technology Assessment and Transfer; and User-Computer Interface. Appointments are for up to one-year periods. Applications will be reviewed beginning February 1 and will be accepted until the positions are filled. Applicants should send vita, including complete publication list, and three references to: Visiting Engineers Scholars Program or Research Faculty and Staff Program, School of Engineering and Applied Science, The George Washington University, Washington, DC 20052. The George Washington University is ■ Affirmative Action and Equal Opportunity Employer.

University of Hawaii at Manoa, Department of Electrical Engineering, invites applicants for tenure-track associate professor or assistant professor positions with specialization in either of the following areas: (1) Computers: Advancement of knowledge and state of the art in high performance computing systems, system software or parallel and distributed algorithms. (2) Electrophysics: Microwave engineering and VLSI. Duties: Teach EE undergraduate and graduate courses, serve on university and department committees, conduct research and scholarly activities, and perform related tasks as assigned. Minimum Qualifications: Associate Professor: Ph.D. degree or completion of all requirements for ■ doctorate in electrical engineering, computer science, and/or equivalent; minimum of four years of full-time college or university teaching at the rank of assistant professor or equivalent, with evidence of increasing professional maturity; demonstrated scholarly achievement in comparison with peers active in the same field; demonstrated ability to plan and organize assigned activities, including the supervision of work of assistants when appropriate; ability to pursue and supervise research; strong commitment to both undergraduate and graduate teaching. Assistant Professor: Ph.D. degree or completion of all requirements for ■ doctorate in electrical engineering, computer science, and/or equivalent; demonstrated ability to teach; demonstrated scholarly achievement; ability to pursue and supervise research; strong commitment to both undergraduate and graduate teaching. Minimum Annual Salary: Associate Professor: $65,568; Assistant Professor: $53,892. Send resume and three references by April 30, 1992 to: Professor Shu Lin, Chairman, Department of Electrical Engineering, University of Hawaii at Manoa, 2540 Dole Street, Holmes Hall 483, Honolulu, HI 96822. An Equal Opportunity/Affirmative Action Employer.

Electrical Engineering: Indiana-Purdue University at Fort Wayne invites applications for one tenure-track assistant professor. Requirements are a B.S. and Ph.D. in electrical engineering with expertise in control, digital systems, computer engineering, and/or electronics or in closely related areas. Teaching experience preferred. Duties include teaching, applied research and service to university and professional societies. Send letter of application and resume with names of three references to Muhammad H. Rashid, Chair of Engineering, IPFW, 2101 Coliseum Boulevard East, Fort Wayne, IN 46805-1499. The closing date is March 27, 1992 or until the position is filled. AA/EOE.

University of California, Irvine. Department of Electrical and Computer Engineering. The Department invites applications from outstanding candidates for several tenure track and tenured faculty positions: Systems and Signal Processing: The department seeks candidates at the level of Assistant or Associate Professor with experience in digital signal processing, adaptive filtering, neural computing, machine vision, spectral analysis, controls, robotics or intelligent systems. It is expected that the candidates will interact with faculty in the areas of integrated electronic circuits, VLSI system design, solid state devices, and parallel processing. Computer Engineering: Senior candidates will be given higher priorities. It is expected that the candidates will have experience in the areas of highly parallel computer systems, distributed computer systems, ultra-reliable real-time computer systems and high-level computer design automation. Senior candidates will be expected to take ■ leadership role in the development of the Computer Engineering Program. Photonics/Electronics Materials and

Related Technologies: The senior candidate for this position is expected to have extensive background and expertise in areas including, but not limited to: a) materials, including III-V and II-VI compound semiconductors, magnetic and polymeric materials, for high-speed photonics; b) processing, fabrication, and characterization of photonic/electronic materials and devices; and c) integrated photonic/electronic devices, interconnections, and packaging. The prospective candidate will be expected to collaborate closely with other faculty members within the Optical and Solid State Device group in order to extend and enhance research programs aimed at the effective vertical integration of materials, devices, and systems. Departmental facilities include a small microfabrication laboratory housing lithographic and processing instrumentation, a molecular beam epitaxy facility, and advanced electronic and photonic device research laboratories. Electronic Circuits: Candidates at the level of Assistant or Associate Professor should have a thorough knowledge of the principles of operation, analysis, and design of analog and digital electronic circuits. In addition, the applicant should possess a strong background in the theory and practice of semi-conductor electronics and be familiar with modern methods for computer-aided design and engineering of integrated electronic systems. The candidate will be expected to take a leading role in the development of departmental research associated with the creation of integrated circuit modules to perform analog and digital functions which will complement existing departmental strength in the area of digital systems. The successful candidate must have an exceptional record of research including a significant publication record in archival research journals. In addition, senior candidates must have a record for obtaining substantial extramural research funding and the inclination to assist younger faculty in their professional development. Please send your resume and names of four references to: Leonard A. Ferrari, Chair, Department of Electrical and Computer Engineering, University of California, Irvine, CA 92717. The Department of Electrical and Computer Engineering welcomes applications from women and minority candidates. UCI is an Affirmative Action/Equal Opportunity Employer.

Center for Laser Science and Engineering. The University of Iowa will expand its activities in the interdisciplinary field of Laser Science and Engineering by making additional tenure-track faculty appointments over the next few years in the general areas of photonics and quantum electronics. These appointments may be made in any existing department or program. Rank and salary will be commensurate with the qualifications and experience of the candidate. Preferred areas of interest include (but are not limited to) development of ultrafast lasers; strong-field science and applications; ultrafast investigations of processes, materials and devices; growth, fabrication, and characterization of traditional and non-traditional photonic materials and devices; and photonic engineering. The successful applicant will be expected to have the potential for establishing an outstanding research program at the University of Iowa and an interest in teaching undergraduate and graduate students. Collaboration with current programs and present faculty is encouraged. Applications will be reviewed starting March 15, 1992, but applications will be accepted until all positions are filled. Women and minorities are encouraged to apply. Applicants should send a complete vitae and the names of three references to: Faculty Screening Committee, Center for Laser Science and Engineering, 124 AMRF, Oakdale Campus, University of Iowa, Iowa City, Iowa 52242 (319) 335-4581. The University of Iowa is an Equal Opportunity/Affirmative Action employer.

University of Virginia, Chair, Department of Systems Engineering. Applications or nominations are invited for the Chair of the Department of Systems Engineering at the University of Virginia. Candidates should have a distinguished record of research, a commitment to teaching, strong administrative and leadership skills, and experience in systems or industrial engineering. Candidates should also be eligible for appointment at the rank of professor; an endowed chair appointment is possible for qualified candidates. The department offers B.S., M.E., M.S., and Ph.D. degrees in Systems Engineering. The faculty has strong research programs in decision theory, intelligent systems, stochastic modeling, data communications, scheduling systems, and risk management. The new Chair must be capable of expanding upon this excellent foundation in both education and research. Applications should contain a current vita and the names, addresses and phone number of four references. The University of Virginia is an Equal Opportunity/Affirmative Action employer and applications are encouraged from minority and female candidates. Applications or nominations will be accepted until the position is filled and should be sent to: Professor James M. Ortega, Chair, Search Committee, Department of Computer Science, University of Virginia, Thornton Hall, Charlottesville, VA 22903-2442.

Ecole Polytechnique De Montreal, Postdoctoral Fellows. "Le Groupe de recherches appliquees en micro-ondes et en electronique spatiale" at Ecole Polytechnique's Department of Electrical and Computer Engineering has opportunities for two new Ph.D. graduates in Non Linear Characterization/Modeling of Microwave Electron Devices and in MMIC Circuits Design. Initial appointment for one year but may be renewed for up to two more years. The language of work at Ecole Polytechnique is French. Salary and conditions: Remuneration and benefits will be determined in accordance with current standards at Ecole Polytechnique. Date of commencement: September 1, 1992. Applications, accompanied by a curriculum vitae and references, and specifying the position applied for, should be sent to the following address (arriving no later than July 31, 1992): Prof. Fadhel M. Ghannouchi, Dept of Electrical and Computer Engineering, Ecole Polytechnique, C.P. 6079, Succ. A, Montreal (Quebec) Canada, H3C 3A7/ Tel: (514) 340-4091, fax (514) 340-3219. In accordance with Canadian and Quebec immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. Ecole Polytechnique is an equal opportunity employer.

Faculty Position in Electrical and Computer Engineering, Portland State University. The Department of Electrical Engineering is seeking to fill tenure-track faculty positions. An earned doctorate and demonstrated teaching and research expertise are required. Applicants for senior positions should have a proven record of scholarly work and show excellence in both teaching and research. The areas of particular interest involve all aspects of Integrated Circuit Design, Semiconductor Devices, Solid-State Electronics, Computer Engineering, and Power Systems, but concomitant teaching and research activities are desirable in other electrical engineering disciplines. Advanced Electrical Engineering research laboratories in the University's Portland Center for Advanced Technology include a VLSI design center, and laboratories for integrated circuit testing, power electronics, computer vision and graphics, and lasers. Faculty members have access to a departmental network of Sparc and Sun workstations, a Sequent multiprocessor machine, as well as university IBM and Sequent computers. Responsibilities include undergraduate and graduate teaching, development of sponsored research, and interaction with local industry. Portland State University is one of the three major universities in the Oregon State System of Higher Education and a member of the Oregon Joint Graduate Schools of Engineering. It is located in Portland, Oregon, with easy access to the well-known recreational opportunities of Oregon's mountains, rivers, and coast. The Department of Electrical Engineering offers B.S., M.S., and Ph.D. degrees in electrical and computer engineering. The Department has 12 full-time faculty and over 300 students admitted to its upper division and graduate programs, with more than 100 M.S. and Ph.D. students. Portland has a rapidly-growing computer and electronics industry including Tektronix, Intel, Hewlett-Packard, Fujitsu, Analogy, NCUBE, Electro-Scientific Industries, Sequent

Create The Next Generation of Digital Wireless Communications Technology

The revolution is happening now at Motorola's Land Mobile Products Sector. This is your opportunity to become a key member of a first class team that will define requirements, architect and design the next generation of digital wireless communications systems. Utilizing advanced digital technology, this system will integrate dispatch land-mobile communications, paging, telephony and data services, from a singular subscriber unit. All levels of R&D positions are now available for Telecommunications engineering experts in the following areas:

RF BASE STATION CONTROL SYSTEMS ENGINEERING AND DEVELOPMENT

High level design definition and development for the base station control system (both call processing and operations and maintenance). Requires a strong background in system and software design for wireless communications systems. BSEE or equivalent plus at least 4-6 years experience required.

NETWORK MANAGEMENT SYSTEMS ENGINEERING AND DEVELOPMENT

Define, architect and develop a state-of-the-art wireless network management system. Requires a strong background in the design of Operations & Management Networks, with a working knowledge of the network management aspects of ISO reference model. BSEE or equivalent plus at least 4-6 years experience required.

If you would like to be a major contributor to this new and exciting development team with the world leader of wireless communications, Motorola would like to hear from you. Send your resume, in confidence, to: **Manager of Professional Recruiting, Dept. #9202, MOTOROLA INC., Land Mobile Products Sector, 1301 E. Algonquin Road, Schaumburg, IL 60196**. An Equal Opportunity/Affirmative Action Employer.

MOTOROLA

Land Mobile Products Sector

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Computer Systems, Metheus, Mentor Graphics, Lattice and many others, which permits close industry-university interaction. Rank and salary are commensurate with qualifications and experience. Send an application, including a resume listing the names of three references to: Dr. Rolf Schaumann, Chair, Department of Electrical Engineering, Portland State University, Portland, Oregon 97207-0751. Phone: (503) 725-3806. Applications will be reviewed starting April 1, 1992 or until the positions are filled. Non-U.S. residents must state their visa status. Portland State University is an equal opportunity/affirmative action employer.

Biomedical Engineering Faculty Positions. Boston University College of Engineering, Department of Biomedical Engineering, anticipates an opening for two tenure-track faculty positions at the assistant, associate, or full professor level effective September 1992. Cardiopulmonary Mechanics seeking outstanding candidates with research interest in cardiopulmonary mechanics to join our existing group in respiratory mechanics. This person will be expected to develop and teach courses in the bioengineering aspects of the cardiovascular system and to conduct an active research program. Requires Ph.D. in engineering or physiology with undergraduate training in engineering. Biomedical Engineering Faculty seeking outstanding candidates with research interests in computational vision, fields/tissue interactions, human/machine interfacing, or biomechanics (electromyography/functional electrical stimulation) to join existing groups. Requires Ph.D. in engineering. Eligible candidates should submit curriculum vitae with names and addresses of at least three references to: Faculty Search Committee, Department of Biomedical Engineering, Boston University, College of Engineering, 44 Cummington St., Boston, MA 02215. Applications will be accepted through June 1992 or until positions are filled. An equal opportunity, affirmative action employer.

Tenure track Associate/Assistant Professor of Biomedical Engineering (BME) at Worcester Polytechnic Institute. WPI offers MS and Ph.D. degrees in BME. Close cooperation exists with the University of Massachusetts Medical School (UMMS), Tufts University School of Veterinary Medicine, local hospitals, and the Massachusetts Biotechnology Research Park. The BME Department also operates a research Nuclear Magnetic Resonance imaging and spectroscopy laboratory in collaboration with the Radiology Dept. at UMMS. Ph.D. in BME, physical science or a related discipline required. Preferred areas of specialization are: medical imaging, biomedical signal processing and application of optics to biomedicine, but all specialties will be given consideration. Applicants should be able to teach a physiological systems course/laboratory. Applicants should be interested in developing a strong research program and be committed to quality teaching. WPI is located near the heart of the high technology focus of New England, yet offers opportunities for urban, suburban, or rural lifestyles. Women and minorities are encouraged to apply. Send resume and names of three (3) or more references to Dr. Robert A. Peura, Chairman, BME Dept., Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609. Tel: (508) 831-5447/Fax: (508) 831-5483. WPI is an affirmative action, equal opportunity employer.

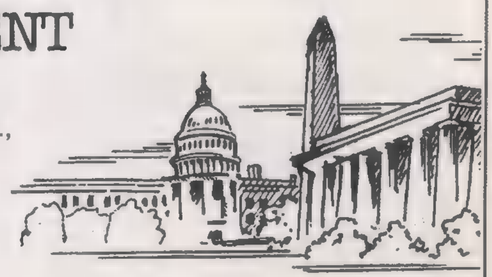
The Naval Postgraduate School (NPS) is seeking candidates for tenure track positions in systems engineering and analysis to support interdisciplinary instruction and research covering a broad range of engineering, analysis, and operations fields. NPS has formal Master's degree programs in anti-submarine warfare, command, control and communications, electronic warfare, space systems operations and space systems engineering. The student body comprises U.S. and international officers of the military services and federal civilians. Positions are at the senior Associate Professor and Professor levels. Successful candidates will have made significant contributions in an interdisciplinary field, including research publications. Qualifications include a doctorate and a serious interest in teaching at the graduate level while pursuing relevant applied research. Salaries and benefits are competitive. The Naval Postgraduate School is an Equal Opportunity Employer. Please send a resume including references to Chairman, Search Committee, Academic Groups (Code CC), Naval Postgraduate School, Monterey, CA 93943.

Government/Industry Positions Open

Development Staff Member: Develop communications and programming interface specifications for systems and network management in the area of performance management. Duties include research and validation of customer requirements in the development of new and novel algorithms for measurement, architectural design for OSI compliant network management, decision and control, analysis of applicable international standards, use of object oriented techniques, and representing the company to standards organizations. As a leadership position, this will also require project planning and management. 40 hrs./wk., $60,007/yr. Must have Ph.D. in electrical engineering, and one yr. exp. on the job or one yr. exp. as a pre or post doctoral research assistant. The one yr. related exp. must include research and development in communication networking, functional analysis, decision theory, and performance analysis as well as experience in algorithm design in mutli-domain environments, flow deviation algorithm, and linear programming technique. Please send resume or letter to: Job Service, 516 North Mangum Street, Durham, NC 27701, Attn.: J.O. #3011204, DOT Code: 003.061.010 cr your nearest Job Service Center.

(Continued on p. 54)

TECHNOLOGY AND MANAGEMENT CONSULTING



Arthur D. Little's Technology Resource Center, located in Washington, D.C., is in its ninth year of technology research and planning for its client, the United States Postal Service. We seek outstanding candidates in the following fields:

MAIL PROCESSING SYSTEMS

Pattern Recognition

Responsibilities include defining, managing, directing and evaluating automated address reading algorithms research and real-time implementation. These positions require expertise in several or all of the following areas: document analysis, pattern recognition, character and word recognition (machine-printed and handwritten), and contextual analysis algorithm development; and real-time implementation and architectural design for document analysis or pattern recognition systems. An M.S. or Ph.D. in Electrical and Computer Engineering, Computer Science, or other closely related field, excellent oral, written, and organizational skills, and 5 or more years of R&D experience are required. Management and supervisory experience are highly desirable, but not required. **Dept. 125**

Electro-Mechanical Systems Engineering

Responsibilities include coordinating requirements and developing activities for a special purpose mail handling system. Extensive experience with development of hardware and software control processes and device interfaces related to high-speed paper handling systems such as check sorters, envelope inserters, etc. is required as well as a demonstrated success in dealing with end users and suppliers of custom components and subsystems. A B.S. in Electrical Engineering, excellent verbal, written and organizational skills, and 5 or more years of R&D and project management experience are desired. **Dept. 126**

Data Structures

Responsibilities include defining, managing, directing and evaluating research and real-time implementation of large-scale and complex data storage and retrieval systems. This position requires experience in several or all of the following areas: data structures and data organization; data compression, storage, and retrieval involving inexact matching; structured analysis and design; large-scale scientific data analysis. An M.S. in Computer Science or other closely related fields, broad exposure to hardware and software, excellent oral, written and organizational skills and 8 or more years of relevant experience are also required. Some project management experience is desirable. **Dept. 127**

Arthur D. Little's Technology Resource Center is providing long-term advanced technology development support for the U.S. Postal Service. This includes support of a contract research program to improve the efficiency of all postal operations. These high-visibility positions offer opportunities for direct client contact, participation in high-level planning and work in a team-oriented, multidisciplinary research environment.

If you are interested in exploring employment opportunities with us, send a resume to the appropriate department number at Arthur D. Little, 20 Acorn Park, Cambridge, MA 02140. We are an equal opportunity employer, M/F.

Arthur D Little

Innovations

(Continued from p. 52)
ery, U.S. patent 4 0992 696 was granted to Prueitt and colleagues on Feb. 12, 1991.

The forces generated by magnetic fields in the wires sometimes rip apart wire conductors using traditional designs, said Prueitt. For example, two wires 10 cm apart and carrying 1 MA each in the same direction, exert a force on each other of 205 metric tons per meter of length. The patented configurations reduce these local forces to zero.

Faster, sharper micromachining

Micromachining porous silicon makes for consistent production of surface and buried insulators, conductors, and the sacrificial layers used in fabricating parts for miniature sensors, motors, and accelerometers. A research team at Sandia National Laboratories in Albuquerque, N.M., developed the process.

In comparison with conventional chemical machining, the etch rate is 10 times as fast, and the finish obtained is highly reflective rather than matte. The mirror finish is superior because it indicates the depth of the porous silicon is uniform, said Terry R. Guilinger, a member of the Sandia team.

Porous silicon micromachining is a two-step process. First, the electrolysis of a silicon wafer in aqueous hydrofluoric acid produces a very thin surface layer of porous silicon. Since the etching rate is directly proportional to the current passed, the depth of porous silicon formation can be readily regulated.

Next, the porous silicon is selectively etched with hydroxide solutions at room temperature. Alternatively, it may be oxidized to form silicon dioxide, and then etched with hydrofluoric acid. Because the pore depths are so uniform, the resultant etch finish is highly reflective and mirror-like.

Porous silicon microprocessing, because of its pronounced doping selectivity, may be used to form supported structures similar to those fabricated using polysilicon films, eliminating the need for poly's high-temperature processing. Being monocrystalline, the structures may be stress-free.

Automation of the new micromachining technique may be easier, too, because process control should be improved by the more accurate and reproducible removal of silicon. Department of Energy patent 4 995 954 has been issued to Terry R. Guilinger, Michael J. Kelly, Samuel B. Martin Jr., Joel O. Stevenson, and Sylvia S. Tsao for this process.

Coordinator: Dana Norvila
Consultants: Ralph H. Baer, Jacob Rabinow

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Academic Positions Open

University of Hartford, College of Engineering, Department of Electrical Engineering, Faculty Position. The University of Hartford invites applications and nominations for an anticipated tenure track faculty position in the Electrical Engineering Department. Established in 1957, the University of Hartford encompasses nine schools and colleges offering a wide range of undergraduate and graduate degree programs. The College of Engineering offers ABET accredited day and evening undergraduate programs in Electrical, Mechanical and Civil Engineering, enrolling 525 undergraduate students on a full and part-time basis. The College began a Master of Engineering degree program in the Fall 1991. Laboratories and facilities on ■ spacious and modern 300 acre campus in West Hartford, Connecticut offer ■ full range of testing, simulation and analytical instrumentation and equipment. The College of Engineering also operates an Engineering Applications Center, with the opportunity for faculty to participate in research and development with local industry. Faculty are also encouraged to teach in the University's nationally recognized interdisciplinary general education curriculum. The full-time faculty position is open in the Electrical Engineering Department at the Assistant Professor level. Criteria for appointment to this position include: —Doctorate in electrical engineering.—Strong interest in teaching at the undergraduate and graduate level.—Strong scholarly activities involving research and/or industrial consulting. Primary background desired for this position are: Communications & Digital Signal processing but applicants with background in Electrical Machinery will also be considered. Applications/Nominations should include a curriculum vitae, a letter of interest, and the names, addresses, and telephone numbers of at least three professional references. Applications should be sent to: Chair, Faculty Search Committee, Electrical Engineering Department, University of Hartford College of Engineering, West Hartford, CT 06117. The University is an equal opportunity/affirmative action employer and specifically invites and encourages applications from women, minorities and members of underrepresented groups.

The University of New South Wales, Sydney, Australia. School of Electrical Engineering. Lecturer (Fixed Term Appointment) in the Department of Communications (Ref. 031). The Department of Communications is one of the four departments within the School of Electrical Engineering. Specialization for undergraduate students commences at the second half of their third year in the four year BE course. The Department also offers graduate degrees in Master of Engineering Science, Master of Engineering and Doctor of Philosophy. The research and consulting activities of the Department cover communications networks; mobile and digital communications; microwave and antenna systems; optical fibre and electro-optics technology; and signal processing including speech processing. The optical communications research group in the Department is well known and has excellent research facilities including optical fibre manufacturing facilities, numerous lasers, and optical waveguide manufacturing equipment for optoelectronic research. We are seeking applicants with a relevant PhD degree and expertise in fibre optics or electro-optics. In addition to research activities, the successful applicants are expected to teach undergraduate and postgraduate subjects within the School. The appointment is for a fixed term of two and a half years. Membership of a University approved superannuation scheme is compulsory for new appointees. Salary: Level B Academic: A$39,463—A$48,688 per annum. Commencing salary according to qualifications and experience. Further information from the Head of the Department, Associate Professor T B Vu on International 61 2 697-4006. Applications close 15 May 1992. Please submit written application, Quoting Reference Number, and include business and private telephone numbers, together with the names, addresses (and preferably facsimile numbers) of at least two referees, curriculum vitae and transcript of academic record to: The Recruitment Officer, Staff Office, PO Box 1, Kensington, NSW 2033, Australia. People from targeted EEO groups are encouraged to apply.

The Australian National University Research School of Physical Sciences and Engineering, Department of Electronic Materials Engineering Professor (Academic Level E), Senior Fellow (Academic Level D)/ Fellow (Academic Level C). Applications are invited for appointment to ■ tenurable research position at academic level C, D, or E in the Department of Electronic Materials Engineering (Head: Professor J.S. Williams), Research School of Physical Sciences and Engineering. The department's semiconductor research program is concerned with the fabrication, processing and characterization of semiconductor structures. It includes: epitaxial growth of III-V semiconductor structures by MOCVD; ion-beam processing and characterization, including secondary ion mass spectrometry; and the use of a variety of other electrical, optical, and microstructural characterization techniques. Applicants should have a strong background in processing and characterization of semiconductors, especially in areas of relevance to the department's research. Preference will be given to candidates with expertise in electronic/optoelectronic device fabrication. Enquiries may be made to Professor Williams, Telephone (616) 249-0020. Closing date: 1 May 1992 Ref: PSE 22.1.1. Salary: Professor; A$73,800 p.a.; Senior Fellow; A$56,375 - A$64,575 p.a.; Fellow; A$44,075—A$56,375 p.a. Appointment: Professor, to retiring age 65, Fellow/Senior Fellow, tenurable. Applications should be submitted in duplicate to the Registrar, The Australian National University, GPO Box 4, Canberra ACT 2601, Australia, quoting reference number and including curriculum vitae, list of publications and names of at least three referees. The University reserves the right not to make an appointment or to appoint by invitation at any time. Further information is available from the Registrar. The University is an Equal Opportunity Employer.

The Swiss Federal Institute of Technology Zurich (ETHZ) invites applications for ■ Faculty Position in Control Systems. The new professor has to contribute to research and teaching in the area of control systems, especially the underlying system theoretical concepts and their applications. Candidates should have experience in research and supervision of research projects in the above area. Teaching at the undergraduate and graduate levels as well as cooperation with other colleagues in the Automatic Control Laboratory and the Department of Electrical Engineering are expected. Cooperation with national and international institutions and with the industry is also essential. Please apply with ■ curriculum vitae, ■ short description of research interests and a list of publications, by April 15, 1992, to the President of ETHZ, Prof. Dr. J. Nuesch, ETH Zentrum, CH-8092 Zurich. In its effort to increase the number of women in academic top positions, the ETHZ specifically invites applications from women.

Applications are invited for the appointment to the post of Professors, Associate Professors, and Assistant Professors for the academic year 1992/1993. The department would welcome well qualified Ph.D. holders in the fields of Computer Engineering (with emphasis on Robotics and Automation, Computer Control, Data Communications, Computer Vision, Neural Computers) to support both teaching and supervision of post graduate theses research. The successful applicants for professorship will be expected to provide leadership and fostering excellence in research, professional activities and policy development in the Dept. of Computer Engineering. Application together with curriculum vitae, list of publications and names of at least three references should be mailed to: Dean, College of Computer & Information Sciences, Kind Saud University, PO Box 51178, Riyadh 11543, Saudi Arabia. The deadline for receiving application is Mar. 31, 1992.

Government/Industry Positions Open

Digital Video Engineer: Coordinate engineering projects for implementation of Joint Photographic Experts Group (JPEG) standards for still pictures, the International Consultative Committee for Telephone and Telegraph (CCITT), and Moving Pictures Experts' Group (MPEG) standards for full motion video; create encoder and decoder designs; design metrics for picture quality control, as well as setup and operation of ■ state-of-the-art laboratory for video signal processing, involving integration of hardware from several vendors; participate in the process of acquisition, storage, processing and display of video signals in several formats; develop proprietary software tools for interactive multimedia, involving use of 'C' programs, DSP code and object-oriented programming of UNIX workstations and personal computers; participate in the development of the Programmer's Interface Kernel, ■ comprehensive software interface with imaging applications, involving digital image processing techniques, such as image enhancement, restoration, digital filtering, Fast Fourier Transforms, feature extraction, and computer graphics. Applicants should possess Ph.D. degree in Electrical Engineering. Ph.D.-level coursework must include electrical engineering. Requirements in related position must include one (1) course in each of the following subjects: 1) Image Reconstruction; 2) Advanced Digital Signal Processing; 3) Detection and Estimation. Ph.D.-level research must include: Quantitative analysis of superresolution algorithms for spatial spectrum estimation and image processing; development of transient signal detection algorithms. 40 hrs./wk.; 9:00 a.m. -5:00 p.m.; $46,800.00/year. Must have proof of legal authority to work permanently in the U.S. if offered employment. Send resumes to Illinois Department of Employment Security, 401 South State Street, 3 South, Chicago, Illinois, 60605. Attn.: E. Reed. Reference # V-IL 4635-I. No Calls. An Employer Paid Ad. Two (2) copies of your resume required.

Development Staff Member: Design and develop ■ networked distributed system which interconnects PC's, PC RT's, RS/6000's, AS/400's and IBM mainframes in a heterogeneous environment. Design and implement user interface and network interface for the AS/400 machines to access and communicate with the system stated above. Utilize IBM PC RT, RS/6000 and AS/400 along with UNIX and OS/400 software tools. 40 hrs./wk., $57,000/yr. Must have Ph.D. in Computer Science and one yr. exp. on the job or one yr. exp. as ■ pre or post doctoral research/teaching assistant. The one yr. related exp. must include research and development in distributed multiprocessor systems and multicomputer network interconnection topologies; UNIX operating system; & related hardware & software development tools. Must be ■ U.S. Citizen or authorized for permanent employment in the United States. Send cover letter and resume to: S. Springmeyer #2-13, MDJT, 390 North Robert Street, Rm. 124, St. Paul, MN 55101.

Project Engineer (Electrical); 40 hrs./wk.; 7:30 am-4:00 pm; $18.19/hr. Job requires: Master's degree w/major field of study Electrical Engineering. Job also reqs.: 1) Grad. level research in control applications as evidenced by Master's thesis or 1 professional publication; 2) 1 grad. crse., in control; 3) 1 grad. crse. in control of step motors; & 4) 2 grad. crses. in computational methods. Job duties: Design, develop, test, troubleshoot, & evaluate electronic controls for electrical power generation equipment & special applications. Design, develop, & evaluate computer software for various applications & customer requirements. Qualified applicants should send two resumes to: Illinois Department of Employment Security, 406 Elm St., Peoria, IL 61605. Attn: Jim Smithers. Ref. No. 4599-B. An Employer Paid Ad.

Comunications Systems Engineer, Sr. Min. PH.D. (Communication System/Theory/ Electrical and Electronics Engineering) plus one year experience. Analysis, computer simulations & design of advanced communication systems. Knowledge of C/MATHLAB/FORTRAN; specif-

READER GUIDE TO PRODUCTS AND SERVICES

ICASSP-92
IEEE 1992 International Conference on ACOUSTICS, SPEECH, and SIGNAL PROCESSING
San Francisco Marriott • San Francisco, California, USA

TECHNICAL PROGRAM
Sponsored by the Institute of Electrical and Electronics Engineers' Signal Processing Society, ICASSP-92 is the 17th in a series of international conferences presenting work in experimental and theoretical signal processing, speech, and acoustics. Major topic areas include: audio and electroacoustics, underwater acoustics signal processing, speech processing, digital signal processing, spectrum estimation and modeling, multidimensional signal processing, very large-scale integration (VLSI) for signal processing, and emerging technologies (such as neural networks, symbolic methods, and artificial intelligence).

TUTORIALS
In addition to technical presentations, half-day tutorials by experts will be offered on March 22: Implementation and Synthesis of VLSI Signal Processing Systems, Introduction to Adaptive Digital Filtering, Articulatory Speech Analysis/Synthesis, and Image Sequence Processing.

EXHIBITS
Leading vendors of hardware and software for signal processing and publishers of signal-processing books and periodicals will be showing their wares at ICASSP-92.

REGISTRATION
Advance registration (before March 13, 1992) is \$375 for IEEE members and \$455 for nonmembers. Reduced registration rates are available for those not wishing to attend the conference banquet and for students. Rates are higher for registration after March 13. On-site rate for IEEE members is \$395, \$475 for nonmembers. Registration forms are available in the Advance Program (mailed to all Signal Processing Society members) or they can be obtained directly from:

Tom Lookabaugh
Publicity, ICASSP '92
Compression Laboratories Inc.
2860 Junction Ave.
San Jose, Calif. 95134

NOMINATIONS SOUGHT FOR CORPORATE RECOGNITIONS

The IEEE is seeking nominations by July 1 for two special awards, known as the IEEE corporate recognitions, for engineering leadership and corporate innovation. They are to be presented at the 1993 IEEE Honors Ceremonies. IEEE members and nonmembers are invited to submit nominations.

The criteria for the recognitions are:

Engineering leadership. The IEEE Engineering Leadership Recognition is given for exceptional managerial leadership in the fields of interest of the IEEE, as reflected in an executive role. The recipient should have attained preeminent stature in the engineering community for inspirational, creative, and professional contributions that have been extraordinarily successful, exemplary, and persuasive in pursuing the theory, planning, implementation, and direction of outstanding achievements, contributions, or service in the field of electrotechnology.

There are no restrictions or preferences as to IEEE membership, nationality, race, sex, creed, or age.

Corporate innovation. The IEEE Corporate Innovation Recognition is given for outstanding and exemplary contributions by an industrial entity, governmental or academic organization, or other corporate body through innovative products, product lines, systems, or concepts that have resulted in major advancement of the arts and sciences of electrotechnology. There are no eligibility restrictions with regard to nationality, location, political persuasion, or position on public issues.

For more information and nomination forms, contact: Staff Secretary, IEEE Awards Board, 345 East 47th St., New York, N.Y. 10017-2394; fax, 212-223-2911.

NEW SELF-STUDY COURSE
THE DESIGN AND APPLICATION OF DIGITAL BUSES

The Educational Activities Department of the IEEE announces the publication of a new self-study course, "The Design and Application of Digital Buses." Today, the emphasis is on networking logic/memory modules so that data and instructions can be shared. This process of transmitting information is called busing, and it requires both the physical medium and an information protocol.

This comprehensive course will help the many people associated with digital design understand the concept and potential use of many digital bus networks. The relationship between and among the protocol, interconnection, performance, and standards is reviewed. Specific topics covered include

(Continued overleaf)

READER SERVICE (CIRCLE NUMBERS)

1 PRODUCT INFORMATION

1	10	19	28	37	46	55	64	73	82	91	100	109	118	127	136	145	154	163	172
2	11	20	29	38	47	56	65	74	83	92	101	110	119	128	137	146	155	164	173
3	12	21	30	39	48	57	66	75	84	93	102	111	120	129	138	147	156	165	174
4	13	22	31	40	49	58	67	76	85	94	103	112	121	130	139	148	157	166	175
5	14	23	32	41	50	59	68	77	86	95	104	113	122	131	140	149	158	167	176
6	15	24	33	42	51	60	69	78	87	96	105	114	123	132	141	150	159	168	177
7	16	25	34	43	52	61	70	79	88	97	106	115	124	133	142	151	160	169	178
8	17	26	35	44	53	62	71	80	89	98	107	116	125	134	143	152	161	170	179
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180

MEMBERSHIP INFORMATION *300 Regular* *301 Student*

Print or Type only
Name ______________________ Title __________
Company ______________________
Address ______________________
City ______________ State ______ Zip __________
Country ______________ Business Phone __________
If this represents a change in address, please fill out form on p. 9

3 ADDITIONAL COMMENTS

____
____
I would like: ______________________
DELIVERY: I received this issue ______________ (date).

For faster information, fax this card to 413-637-4343

3

Void after June 1, 1992 *Void overseas July 1, 1992*

READER FEEDBACK (CIRCLE NUMBERS)

2 EDITORIAL MATTER

Article/item	Comment		
	Too simple	Just right	Too detailed
Special report: Digital video			
Imaging world	01	02	03
Video format	04	05	06
Applying standards	07	08	09
FPGA software	10	11	12
Disaster recovery	13	14	15
Curriculum reform	16	17	18
Bats and radar	19	20	21
Maxwell's equations	22	23	24
U.S. competitiveness	25	26	27
Newslog	28	29	30
EEs' tools & toys	31	32	33
Innovations	34	35	36
Program notes	37	38	39

Did you find this material stimulating or thought-provoking?

Item	Yes	No
Spectral lines	40	41
Forum	42	43
Books	44	45
Reflections	46	47
Speakout	48	49

READER GUIDE TO PRODUCTS AND SERVICES

printed-circuit interconnection design, transmission line reflections, pulse cross talk, and transceiver technology and design.

This course contains a study guide, workbook, answer book, diskette, final exam, and two product databooks from leading manufacturers.

For more information on this course and other continuing education materials, call 908-562-5498, or CIRCLE # 81 on the Reader Service Card.

NEW BOOKS FROM THE IEEE PRESS

DIGITAL MOS INTEGRATED CIRCUITS II
With Applications to Processors and Memory Design
Edited by Mohamed I. Elmasry, University of Waterloo, Ontario, Canada

Representing today's key research work in digital MOS integrated circuits, this book offers the most comprehensive, up-to-date information on a field that has witnessed phenomenal advances over the past 10 years. Of great value to MOS digital circuit and system designers as well as researchers, *Digital MOS Integrated Circuits II* covers the most recent developments in digital MOS ICs and their applications in memory, signal and data processing, and application-specific ICs.

December 1991 ISBN 0-87942-275-0
Order #PC02691-PNE Approx. 488 pp.
IEEE Member Price: $55.00 List Price: $69.95

UNDERSTANDING LASERS*
An Entry-Level Guide
by Jeff Hecht Sr., Contributing Editor, *Laser and Optronics Magazine*

This introductory guide explains how lasers work and how they are used in the real world of medicine, telephones, compact discs, and supermarket checkout lanes. Written for students, hobbyists, and the just plain curious, this authoritative text is clear, succinct, and amply illustrated—an ideal tool and a valuable reference for technical and nontechnical readers alike.

November 1991 ISBN 0-87942-298-X
Order #PP02931-PNE 448 pp., softcover
IEEE Member Price: $20.00 List Price: $24.95

*This is the IEEE edition of a book previously published by Howard W. Sams and Company under the title *Understanding Lasers.*

To order, call 1-800-678-IEEE. For more information, CIRCLE # 82 on the Reader Service Card.

The Standards Tool for Today's Power Engineer

IEEE STANDARDS COLLECTIONS

For many engineers, purchasing groups of similar standards individually may not be practical or economical. Typically, engineers require groups of standards that deal with specific technologies. When packaged together, these standards collections prove invaluable to today's engineers, making it easier for them to perform their jobs effectively.

Now available:
IEEE C57 Standards Collection, Winter 1992 Edition
Distribution, Power, and Regulating Transformers (ISBN 1-55937-182-X) Product Number: SH14902
Member Price: $94.50 List Price: $135.00

Updated to include 63 of the most current IEEE and ANSI standards on power distribution and regulating transformers, the IEEE C57 Collection is a must for today's power engineers worldwide.

Order today and enjoy the convenience and savings provided by IEEE Standards collections.

Call toll free 1-800-678-IEEE in the United States and Canada. Outside the United States and Canada, call 908-981-1393.

For more information on IEEE Standards Collections, CIRCLE # 83 on the Reader Service Card.

NOMINATIONS INVITED FOR IEEE COMMITTEES, BOARDS

All individual members and IEEE organizational units are invited to participate in the nomination of candidates to be considered by the Nominations and Appointments Committee for appointment to the following 1993 IEEE standing Committees and Boards: Admission and Advancement Committee; Awards Board; Credentials Committee; Educational Activities Board; Fellow Committee; History Committee; IEEE Employee Benefits Committee; IEEE Facilities Committee; Individual Benefits and Services Committee; Nominations and Appointments Committee; Publications Board; Strategic Planning Committee; Tellers Committee; and United States Activities Board.

The general qualifications for committee and board service are the same as those for any other position of leadership responsibility: competence, experience, willingness to take on the task, availability of time to participate, enthusiasm, vigor, and cooperation with others in achieving the objectives of the committee or board.

April 1 is the deadline for the submission of nominations to the Staff Secretary, Nominations and Appointments Committee, IEEE Headquarters, 345 East 47th St., New York, N.Y. 10017-2394. Nomination forms and guidelines for the preparation of nominations are available upon request from the Staff Secretary.

ic academic work in communication theory and systems, forward error correction, algorithms, detection theory, DSP, mathematical foundations of random processes, probability theory and information theory. Knowledge of digital storage (magnetic recordings). Job site/interview: San Diego, CA. Salary $58,000/yr. Send this ad and your resume to Job #ET-3338, P.O. Box 9560, Sacramento, CA 95823-0560, not later than 3/30/92.

Lead Electrical Engineer. Lead electrical engineer directing efforts of research team to develop new concepts for the production of more energy efficient proprietary electrical power & control systems for the company's lines of electric appliances, & design & test prototypes. Using Fortran, Pascal, C & Assembly computer languages & PSpice, ACSL, Finite Element Analysis, SABER & IMSL computer-aided design tools, perform research on induction machine drives to produce efficiency maximization control & implementation of new vector control strategies; design, modeling & simulation of switched reluctance, permanent magnet, induction, & synchronous reluctance motors & complete drive & control systems; develop a design methodology & a design program for switched reluctance motors; design variable speed switched reluctance motor drive system; design & analysis of resonant convertors & AC-DC, DC-DC, & DC-AC power electronic convertors. 40 hrs/wk. 8:00-4:30; $52,000/yr. Overtime as necessary. Must have Ph.D. in Electrical Engineering & 4 yrs. experience as Lead Electrical Engineer or 4 yrs. experience as University Teacher/Professor in Electrical Engineering. Teaching & Research experience required must have included power electronics & must have used ACSL & PSpice in research. To perform the original research required of the job, must have published results of research at least one time in referred professional journal; have done research in the modeling & design of high efficiency drive systems involving switched reluctance, electronic commutated & invertor driven fractional horsepower motors & power supply & switching circuits compatible with electromagnetic devices. Send resume to 7310 Woodward Ave., Rm. 415, Detroit, MI 48202; Ref. No. 89191. An employer paid ad.

A limited number of Postdoctoral Fellowship positions will be available in the fall of 1992 for research in ocean engineering. Research areas include engineering mechanics, marine materials, robotics, electrical and optical engineering. Deadline for application is 15 April 1992. Specify area of interest with request for information brochure and application packet from: Kathy Morton, Postdoctoral Program, Harbor-Branch Institution, Inc., 5600 Old Dixie Highway, Fort Pierce, Florida 34946. An Equal Opportunity Employer.

Department Project Engineer II (Power Division)—Supervise personnel in Greenville, S.C. in performing integrated engineering work associated with design of generating systems and medium and high voltage power systems associated with utility type power generating stations for Canadian market. Direct and coordinate development engineering proposals for client review. Recommend alternate designs and specifications. Supervise assigned personnel to ensure overall development of design and cost considerations. Review and approve for client submittal all engineering drawings, specifications and estimates. Assume responsibility for design schedule, budget and quality. Requires bachelor's degree in electrical engineering and eight years experience in job offered or in related occupation involving heavy industrial electrical systems design, including at least 5 years of supervisory experience. Also requires registration as professional engineer in a Canadian province; ability to understand and perform required analytical calculations (short circuit, load-flow, protective device coordination, etc.); ability to understand, interpret and apply power industry electrical codes and standards; ability to specify, design and apply generators, medium and high voltage circuit breakers, cables, fuses, transformers, batteries, uninterruptable power supplies, buses, motors, protective relays and application schemes. Salary ranges: $57,910 to 66,890 annually depending on experience and educational level. Apply in person or by resume to: S.C. Job Service, 706 Pendleton St., P.O. Box 328, Greenville, S.C. 29601.

Programmer—Information Systems—Dev., install & maintain complex Monitoring & Control software for a multi-tasking UNIX applic. used by a satellite-based commun. netwk. & software to drive a proprietary commun. protocol between host computer & channel devices. Configure, maintain & tune the operating sys. for max. utilization. Knowl. of C lang., semaphores, interprocess commun., queues, distributed databases and perf. anal. Rqmts: M.S. in Computer Science and 2 yrs. exper. as Software Engr. or Teaching Asst. in Computer Science field. M-F, 40 hr./wk., 8:30-5:00; Sal: $36,868/yr. Mail resume & copy of ad to MD DEED, 1100 N. Eutaw St., Rm. 212, Balto., MD 21201; JO # 9049213; Job Location: Clarksburg, MD.

Electrical Engineer V needed to design, develop and maintain performance-driven placement & routing tools as well as timing-driven buffer sizing tool for cell-based IC design. Must have: Ph.D. in Computer Science; 3 graduate credit hours or 6 months exper with VLSI design; 2 yrs work exper or research in place & route system methods incl. graph theory & optimization algorithms (incl. simulated annealing algorithms together w/ normalized Polish expression representation). Salary Range: $51,870-$65,400/year, 40 hrs/week, in Bellevue, WA. Send resume by 4/5/92 to: Employment Security Dept., E&T Div., Attn: AEC Unit, Job #295152, P.O. Box 9046, Olympia, WA 98507-9046. EOE.

Power Distribution/Gen & instrumentation exceptional opptys nationwide/int'l $45-86K. Confidential resume to Gresham & Gresham, employment consultants, P.O. Box 820888, Houston, TX 77282. Will call home. Est. 1966 Mem. AIChE, ISA, SPE (713) 780-1000 FAX 781-3300.

Software Engineer, Lead by March 31, 1992, Please send resume to: Emloyment Security Department, ES Division, Job #295479-P Olympia, WA 98504. Job Description: Designs, implements and tests complex and high level systems and software for mainframe and micro computers. Assumes lead responsibility to design and implement financial applications software, including query systems and user interface, for development of multidimensional consolidated corporate budget and for other corporate financial reporting, utilizing "C" language, FCS modelling language, and VAX/VMS and Windows operating system. Must train in-house staff in use of financial systems software. Requirements: Bachelor's Degree in Electrical Engineering, Computer Science, Mathematics or Physics; four years of work experience in design and implementation of software for multidimensional consolidated budgets and other financial reporting for organization with minimum of $100,000,000.00 annual budget. Must include six months work experience in programming or computer software design utilizing "C" and query langauges, FCS modelling language, VAX/VMS operating system, windowing environment, IBM-PCs design of user interface, software, and training users in software use. Must have proof of legal authority to work in the United States. Job Location: Seattle Area Employer. Salary: $47,000-50,000 per annum. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE.

Advanced Ph.D. Research Scientist. Major automotive manufacturing company seeks Electrical Engineer at Ph.D. level with a sensor technology background to conduct and manage basic scientific research projects and staff. Develop long range research on exhaust sensors for better engine control, lower emissions, better driveability and better fuel efficiency. Analyze the physiochemical processes influencing the stability and selectivity of gas sensors using the Auger Spectroscopy and Mass Spectroscopy. Develop and implement exhaust gas oxygen computer modeling. Research and develop sensors for monitoring the Three-Way Catalytic converter efficiency. Sensorwork involves the fabrication and testing of sensors both in the laboratory and on engines. Position requires a Ph.D. in Electrical Engineering combined with advanced research in sensor technology. Must have at least two (2) month experience in Japanese sensor fabrication processes. Experience must also include a minimum of two (2) years in fabrication technology and solid state and theoretical physics. Must have published at least 5 refereed research papers in this field in last 3 years. Full time Salaried Position: $57,960/year. For Interview Selection and Appointment, send Resume to: Michigan Employment Security Commission, 7310 Woodward Avenue, Room 415, Detroit, MI 48202, Reference No. 85991. Employer Paid Advertisement, An Equal Opportunity Employer.

International Telecommunications Research/Development firm in Oregon needs Engineering Product Manager. Duties include Competition Analysis, Technology Planning, Strategic Planning, Product Definition, Pricing and Documentation in both North American and International Markets. An M.S.E.E. or equivalent degree in Electrical or Electronic Engineering and a minimum of ten years experience in Telecommunications Research and Development, one of which has been in design of radio and Fiber Optic based Transmission Control Software, is required and must include experience in Computer Network Achitectures in Communications and Telecommunications including development of Software, Computer Applications, Data Communications and Telecommunications, Products, Architectures, Protocols and Services, utilizing expertise in OSI, TCP/IP, IEEE 802.x, IN/AIN/SCAI, T1/T3/SONET Transmission, FDDI, SMDS, ISDN, SS7, B-ISDN/ATM, Frame Relay, PCS, CT2, CT2 Plus, PCN, and Enterprise Networking including SNA/DIA and LANs/WANs/MANs. Incumbent will manage and direct Development of Multimedia, Broadband, and Wireless Applications/Services such as Medical Imaging, Image/Information Management and Medical Relief Networks. Salary $92,500 for 40 hour week. Mail resume to: Employment Division, Atten: Job Order Number 5550254, 875 Union N.E., Room 201, Salem, Oregon 97311.

In Vancouver, WA. Process Control Engineer to install, service, program, and maintain computer software, hardware and peripheral equipment for digital process automation control systems in the pulp industry in the U.S. West Coast region; conduct operational/performance testing to diagnose and rectify system malfunctions; train customer engineers to operate systems; provide technical assistance and support to sales staff; analyze and interpret engineering data and prepare technical reports. Must have Bachelor's degree in Computer Technology, Computer Information Systems, or Computer Science as well as either two years experience in job offered or four years experience as Sales Engineer, Sales Manager, Product Manager, or Research Engineer or similar job in process control analysis field (which must include technical engineering of process automation control systems/components, with at least 12 months in process automation control as applied to the pulp industry). Extensive travel throughout U.S. West Coast required. Verifiable references (2) and proof of legal authority to work in U.S. required. Salary: $60,000 per annum. By April 5, send resume to: Employment Security Department, E&T Div., Job #298560, P.O. Box 9046, Olympia, WA 98507-9046.

Government/Industry Positions Wanted

Applied Mathematician (M.S. plus 1 year graduate work) retired from federal microwave measurements laboratory seeks temporary position (less than 6 months) in R & D project. Publications in guided wave systems. Prefer numerical math methods and coding in electromagnetic fields. Fortran or Rocky Mountain Basic. I have 486 PC. (303) 494-8405 or (904) 795-1639.

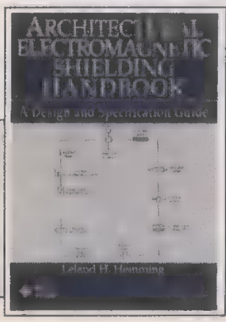
EE-Motors—AC/DC over 20 years exp. Write details of opening to: IEEE Spectrum, Box 3-1, 345 East 47th St., New York, NY 10017.

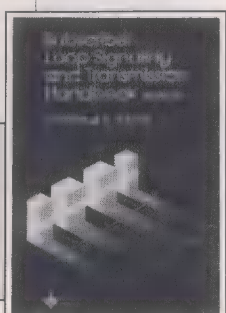
Authoritative Books by the World's Most Highly Recognized Experts in Electronics and Computing Engineering

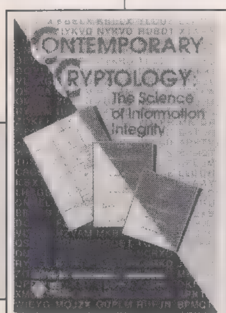
NEW BOOKS
FROM THE IEEE PRESS

CONTEMPORARY CRYPTOLOGY
The Science of Information Integrity
edited by Gustavus J. Simmons, Sandia National Laboratories
Written by those at the very forefront of the field, **Contemporary Cryptology** covers all aspects of the science of information integrity -- from the simplest concepts to the latest research. It provides a practical guide to the algorithms, protocols, applications, and essential literature on information integrity.
November 1991
ISBN 0-87942-277-7
Order #PC02717 656pp
List: $79.95 IEEE Member: $60.00

SUBSCRIBER LOOP SIGNALING AND TRANSMISSION HANDBOOK Analog
by Whitham D. Reeve, Reeve Consulting Engineers
This practical telecommunications handbook provides the latest techniques in designing, maintaining, and using subscriber loops in both public and private networks.
November 1991
ISBN 0-87942-274-2
Order #PC02683 304pp
List: $59.95 IEEE Member: $47.50







ARCHITECTURAL ELECTROMAGNETIC SHIELDING HANDBOOK
A Design and Specification Guide
by Leland H. Hemming, McDonnell Douglas Technologies, Inc.
A complete source of design and specification data for architects and engineers, this handbook shows how to determine the best type of electromagnetic shielding to use in planning and constructing a new or remodeled facility.
August 1991
ISBN 0-87942-287-4
Order #PC02824 240pp
List: $59.95 IEEE Member: $47.50

MODERN POWER ELECTRONICS
edited by B.K. Bose, University of Tennessee, Knoxville
This up-to-date and authoritative survey of current power electronics technology and energy saving applications focuses on power semiconductor devices, AC-DC converters, AC-AC converters, DC-DC converters, DC-AC converters, PWM methods, and converter applications.
December 1991
ISBN 0-87942-282-3
Order #PC02766 608pp
List: $69.95 IEEE Member: $55.00

COMPUTATIONAL ELECTROMAGNETICS
Frequency-Domain Method of Moments
edited by Edmund K. Miller, Los Alamos National Laboratory, Lou Medgyesi-Mitschang, McDonnell Douglas Corporation, and Edward H. Newman, Ohio State University
A practical guide to moment-method EM modeling, **Computational Electro magnetics** delivers concrete information from the world's foremost experts on frequency-domain and integral-equation models and demonstrates their practical application for analysts, designers, and experimentalists.
December 1991
ISBN 0-87942-276-9
Order #PC02709 528pp
List: $69.95 IEEE Member: $55.00

GENERALIZED VECTOR AND DYADIC ANALYSIS: Applied Mathematics in Field Theory
by Chen-To Tai, University of Michigan
An indispensable reference tool for engineers, mathematicians, and physicists, this book offers details on previously unpublished methods of treating and presenting vector and dyadic analysis. Dr. Tai presents original findings on a new symbolic method with the aid of a symbolic vector.
September 1991
ISBN 0-87942-288-2
Order #PC02832 144pp
List: $39.95 IEEE Member: $32.00

WRITING AND SPEAKING IN THE TECHNOLOGY PROFESSIONS
A Practical Guide
edited by David F. Beer, University of Texas, Austin
Did you know that 20 to 50% of a technology professional's time is spent communicating with others? This book delivers concrete advice from foremost experts on how to write technical documents that are clear and effective, give oral presentations more confidently, present information visually using graphics, and much more!
August 1991
ISBN 0-87942-284-X, softcover
Order #PP02782 278pp
List: $29.95 IEEE Member: $24.00

OVERSAMPLING DELTA-SIGMA DATA CONVERTERS
Theory, Design, and Simulation
edited by James Candy, AT&T Bell Laboratories, and Gabor C. Temes, UCLA and Oregon State University
A valuable reference tool for electrical engineers who design or use circuits for signal processing in communications, audio applications, sonar, and instrumentation, this book provides a survey of oversampling methods used for high resolution A/D and D/A conversion.
August 1991
ISBN 0-87942-285-8
Order #PC02741 512pp
List: $69.95 IEEE Member: $55.00

DISCRETE EVENT DYNAMIC SYSTEMS
Analyzing Complexity and Performance in the Modern World
edited by Yu-Chi Ho, Harvard University
Comprehensive and up to date, this is the first volume ever published on formal mathematical models for discrete event dynamic systems including: automated manufacturing plants, computer communication networks, air-traffic systems, military logistic systems, service organizations of multinational companies, large hospitals, and other complex organizations.
September 1991
ISBN 0-87942-281-5
Order #PC02758 304pp
List: $54.95 IEEE Member: $45.00

ADVANCES IN ADAPTIVE CONTROL
edited by Kumpati S. Narendra, Yale University, Romeo Ortega, National University of Mexico, and Peter Dorato, University of New Mexico
Written by leaders in adaptive control technology, this volume reports on the current status of adaptive control of linear, nonlinear, and stochastic systems as evidenced by recent developments.
June 1991
ISBN 0-87942-278-5
Order #PC02725 424pp
List: $69.95 IEEE Member: $55.00

Back In Print!
PROBABILISTIC RISK ASSESSMENT*
Reliability Engineering, Design, and Analysis
by Ernest J. Henley, University of Houston, and Hiromitsu Kumamoto, Kyoto University, Japan
In this self-contained treatment on the new reliability and risk assessment technology, the authors include chapters on such significant topics as confidence limits for reliability parameters, Markov and Monte Carlo methods, and system quantification for dependent basic events.
September 1991, Softcover
ISBN 0-87942-290-4
Order #PP02857 592pp
List: $49.95 IEEE Member:$40.00
*This is the IEEE edition of a book previously published by Prentice Hall under the title: *Reliability Engineering and Risk Assessment.*

All titles are hardcover and are available now except where noted. Prices are subject to change without notice.

Address orders and inquiries to:
IEEE Service Center
Customer Service Department
445 Hoes Lane P.O. Box 1331
Piscataway, NJ 08855-1331
1-800-678-IEEE (4333)

The Institute of Electrical and Electronics Engineers, Inc.

EEs' tools & toys

Equations on disk

Ever need an equation when doing math calculations on your computer? You probably had to hunt through a handbook for it and then type it in.

But with the electronic handbooks introduced this month by MathSoft Inc., you simply search the handbook electronically for the equation you need, change the variables to fit your requirements, and have the answer calculated almost instantly. Or, with a simple mouse double-click, you can transfer the equations to your application and carry out the calculations there. Other items in the handbooks—like formulas and diagrams—can be transferred as well.

So far, MathSoft has three handbooks, which all run under the company's Mathcad 3.1 technical calculation software, for IBM PCs using Microsoft Windows 3.0. One is Tyler Hicks's Machine Design and Analysis section from McGraw-Hill's *Standard Handbook of Engineering Calculations*. Another is based on *The CRC Materials Science and Engineering Handbook*, published last December by the CRC Division of Times-Mirror Corp. The third, completely new, is the *Mathcad Treasury of Methods and Formulas*, which describes the functions and features available in Mathcad.

On 5.25- or 3.5-inch disks, the handbooks are US $99 each for Machine Design and Analysis and the Mathcad Treasury, and $149 for the CRC Handbook. The three handbooks are available on CD-ROM for $199. *Contact: MathSoft Inc., 201 Broadway, Cambridge, Mass. 02139; 800-628-4223 or 617-577-1017; fax, 617-577-8829; or* **circle 101.**

GENERAL INTEREST

To water or not to water?

The electronic Water-Me bird tells owners of house plants when their plants need watering. When its 15-cm-long brass legs are inserted into the soil, a circuit within the bird's ceramic body measures the soil's resistance to current and hence its moisture. The bird "chirps" when the plant it is pro-


Cathy Wassylenko

tecting needs watering. The device utilizes the fact that soil becomes resistive to current as it dries. Chirping starts when the soil dries to the threshold resistance set by an adjustable potentiometer.

The Water-Me bird uses a lithium manganese dioxide battery with a rated capacity of 260 mAh, but the current drawn by the circuit ranges only from 2 to 4 mA when not beeping and 10 to 15 mA when beeping. At this rate, the battery lasts more than five years, says the developer. The gadget works best for potted plants where soil depth is less than 30 cm. The Water-Me sells for $14.95. *Contact: Donald Limuti, 109 Lake St. S, #4, Kirkland, Wash. 98083; 206-822-5423; or* **circle 102.**

COMPUTERS

Networking the software developer

A new software product, NetMake, increases the productivity of software developers by allowing them to compile individual program modules on separate machines in a network. According to Aggregate Computing Inc., this can speed up large compiles by many factors.

The software is a parallel version of the Unix Make utility, which allows a software developer to use only one machine. NetMake permits these developers to use all the machines on their network as a single, aggregate computing resource.

NetMake is available for a minimum of five terminals. The introductory package to be used for networking this number of terminals is priced at $5000. *Contact: Aggregate Computing Inc., 5217 Wayzata Blvd., Suite 125, Minneapolis, Minn. 55416; 612-546-5579; fax, 612-546-9485; or* **circle 103.**

Conference calls by PC

Groups of people at geographically separated computer terminals can now set up electronic conferences in which they share written and graphic information. With Aspects, conferees on separate Macintosh computers may see and edit the same document, with changes appearing instantly on each conferee's computer. Whether people are across the hall or across the ocean, they can work together to sketch ideas and edit documents, producing timely, high-quality results. And with Aspects, notes on what happened are available on disk, rather than on sheets of paper.

The software, for Macintosh computers, comes in packages of 1, 5, or 10 copies; cost is $299, $895, and $1295, respectively. *Contact: Group Technologies Inc., 1408 North Fillmore St., Suite 10, Arlington, Va. 22201; 703-528-1555; fax, 703-528-3296; Email, group.tech&applelink.apple.com; or* **circle 104.**

EDUCATION

Math handbook plus

A cloth-bound handbook consisting of all the mathematical functions that arise in physical and engineering problems is an indispensable reference for engineers. With over 1000 pages, *The Handbook of Mathematical Functions* is the first technical handbook, according to its publisher, to supplement every mathematical function with formulas, graphs, and mathematical tables. The handbook also serves as a quick reference to all the mathematical functions required to solve most engineering problems. It is priced at $75. *Contact: Polywog Press, 333 Jay St., Suite 655, Brooklyn, N.Y. 11201; 718-260-3944; or fax, 718-260-3136; or* **circle 105.**

COORDINATOR: George Likourezos
CONSULTANT: Paul A.T. Wolfgang, Boeing Helicopters

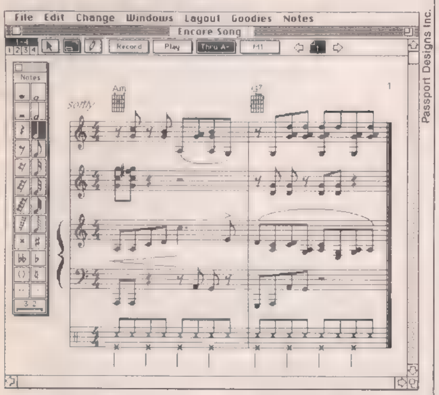
Program notes

Composer on call

The MIDI (pronounced "middy") standard gave form to the revolution in music begun by the synthesizer. *The Microsoft Computer Dictionary* reports, "The standardization on the Musical Instrument Digital Interface by the major synthesizer manufacturers is partially responsible for the huge success of computers in the music industry." Now, MIDI is creating a new software industry.

A MIDI music system typically consists of a computer, one or more synthesizers, and one or more sequencers. It transmits information from one component to another in the MIDI message format—8-bit packets that describe frequency, loudness, duration and other attributes of sound. Packets generated by the synthesizer may be stored for replay or further manipulation.

Programming techniques developed for artificial intelligence (AI) can be used to write software to process the packetized song—for example, adding harmony to a melody. For highly stylized musical forms, smarter software can even create full orchestra arrangements.



This editing screen is part of a typical music-scoring program, Encore. The program generates the starting score from a file of packets on a Macintosh or IBM-compatible computer. The packets conform to the Musical Instrument Digital Interface (MIDI). The file may be synthesizer keyboard input that has been converted to MIDI packets or the output of another music program. The score is then edited with the tools represented by the icons on the left side of the screen. The edited score is printed out or converted into a MIDI file that is downloaded to the synthesizer and sequencer.

Software that creates "new" music from a digitized song is another application of AI techniques. Here, the form and pattern of the reference song are used to produce many variations on the original theme. Another use is music distribution. In MIDI format, hundreds of pages of sheet music can be handily stored on just a single compact-disc (CD) ROM.

MusicWriter, a Los Gatos, Calif., company, is taking this idea to its logical conclusion. It is marketing the NoteStation, a computer with a laser printer plus a modem to access the MusicWriter music database. At music stores that offer NoteStation customers can download a MIDI file of sheet music for any song in the MusicWriter database, and NoteStation arranges it for them, writing it in a key they can play or in a voice range they can sing. *For more on Encore, contact: Passport Designs Inc., 100 Stone Pine Rd., Half Moon Bay, Calif. 94019; 415-726-0280; or* **circle 106.** *For more on NoteStation, contact: MusicWriter Inc., 170 Knowles Dr., #203, Los Gatos, Calif. 95030; 408-364-2500; or* **circle 107.**

The hobgoblin of consistency

Style in writing at its most sublime calls up memories of the Gettysburg address. But at its least ambitious it boils down to good grammar plus tidiness—consistency in spelling, capitalization, punctuation—just the job for a computer. Certainly, many programmers have written software that checks documents for compliance with rules in these areas.

On the one hand, general-purpose grammar-checking programs must allow considerable variation in usage, even within the document, if they are not to dictate how the author is to write. On the other, internal style consistency does make documents easier to read.

Most commercial programs do a good job checking items listed in the Associated Press Stylebook. Unfortunately, for engineering applications, newspaper or magazine stylebooks must be heavily supplemented to cover applications notes, data books, and other technical documents. So, even a grammar-checking program that implements the rules in a stylebook may not be useful to engineers.

A programmer may use a macro language to build custom style sheets. For example, Grammatik IV by Reference Software has a simple English-like macro language for building local style sheets. The rule @#/ micro switch \ Always use MICRO SWITCH flags every occurrence of the phrase "micro switch" and displays the message "Always use MICRO SWITCH." Grammatik also supplies a rule editor to make creating and editing rules exceptionally easy. *Contact: Reference Software, 330 Townsend St., Suite 123, San Francisco, Calif. 94107, 408-541-0222; or* **circle 108.**

The '90s electronic underground press

In the 1960s, the work of many soon-to-be-famous graphic artists and authors was found in underground newspapers. The lurid tabloids, published by two or three activists and printed on an irregular schedule, were sold on street corners and in radical book stores, and paid badly if ever. However, these magazines (some of which are still in print) were often the only place to publish their work.

What will be the 1990s equivalent of the underground press? Maybe the existing network of computer bulletin boards and distributors of shareware software. The "try before you buy, pay if you like it" ethic of shareware users appeals to those who cannot publish through traditional outlets.

Five trends make the electronic underground press possible.

- A large number of computer users are interested in art and books.
- Many artists and writers are willing to publish electronically.
- File format consolidation and translation programs make electronic images and text universal.
- Standardized viewing programs make electronic images and text more like printed material.
- Large floppies, hard disks, and CD ROMs lower distribution costs.

By now file format consolidation and translation programs have made electronic images and text universally accessible. Generic graphics formats can be imported into most graphic programs, while most word processor programs will accept generic text formats like TXT and RTF and cross-platform text formats like Microsoft's DOC and WordPerfect's WP. So, the artist or author needs only to distribute the work in one format to make it universally available. As for their audience, standardized viewing programs simplify access to images and text. Many shareware programs display images or text like a book. Also, commercial viewing programs for hypertext and hyperimages offer viewers a flexibility beyond the reach of printed material.

COORDINATOR: John R. Hines
CONSULTANTS: Stuart Feldman, Computer Systems Research, Bellcore, and John Kellum, Intergraph Advanced Processor Division

John R. Hines (M) is silicon sensors engineer at Honeywell's Micro Switch Division, Richardson, Texas.

ADVERTISING RATES

1 Insertion—$320 12 Insertions—$3840

50% discount to IEEE members [redacted] three or more insertions.
If you are an IEEE member, please enclose your membership number with the order.
Copy cannot exceed 1-inch in depth. No product may be offered for sale.
Advertising restricted to professional engineering and consulting services.
No orders can be accepted by telephone; order and copy must be sent together.
For any further information and closing dates please contact:
Advertising Production, 212-705-7579

LEONARD R. KAHN, P.E.

Consultant in Communications and Electronics
Single Sideband and Frequency Shift Systems
Diversify Reception - Stereophonic Systems
Modulation Systems
Registered Patent Agent

222 Westbury Ave.
Carle Place, NY 11514
516-222-2221

CONSULTING & PROTOTYPES

ELECTRIC MOTORS

BRUSHLESS MOTORS SWITCHED RELUCTANCE
STEPPING MOTORS AC INDUCTION

MAGNA PHYSICS CORP. JAMES R. HENDERSHOT
144 E. Main St., Suite 203 TEL: 513-393-9835
P.O. Box 78 513-393-3810
HILLSBORO, OH 45133 FAX: 513-393-9836

THE CONSULTING GROUP

Multi-Dispciplined Engineers with P.E./Ph.D.
- Microwave, RF, Fiber-Optic Systems Design
- Oscillators, Amplifiers, Filters, Antennas, Synthesizer/PLL Design. Microprocessor, Communication ckts. Industrial Power System. R&D, Prototyping & Testing in our Lab facilities.

71-25 Austin St., Forest Hills, NY 11375
Ph. (718) 793-0777 Fax (718) 793-0770

International Compliance Corporation

Design, Test, & Consulting
- FCC Certification/Verification
- VDE, CISPR, VCCI (Japan)
- "1992" European Compliance Testing
- Product Safety: UL, CSA, IEC, VDE
- Electrostatic Discharge (ESD)
- MIL-STD 461/462, NARTE-Certified Engineer

812 Office Park Circle (214) 221-7071
Lewisville, Texas 75057 TELEX: 403482 (ICC DAL)

INTEGRATED CIRCUIT DESIGN CONSULTING

Providing integrated circuit design and analysis consulting services with gate arrays, cell libraries, or full custom in digital, analog, cmos, bipolar or ecl technologies and support services such as modeling, layout, verification, software, testing, debugging, documentation, and reverse engineering.

1556 Halford Ave, Ste 310 Santa Clara, CA 95051
(408) 243-7422

RAINES ELECTROMAGNETICS

Consulting Since 1972
- Antennas and Arrays
- Scattering and Radar Cross Sections
- Radhaz & Environmental Impact
- Simulations of Fields & Phenomena

Jeremy K. Raines, Ph.D., P.E.
President (301) 279-2972

IOCC

INTEGRATED OPTICAL CIRCUIT CONSULTANTS

Consulting, Contract R&D, and Prototyping
Integrated, Fiber, and Guided-Wave Optics
- Applications Engineering
- Design, Fabrication and Evaluation
- Critical Analysis of Technology
- Troubleshooting
- Marketing

R.A. Becker, D. Sc.
President 10482 Chisholm Ave.
(408) 446-9812 Cupertino, CA 95014

O.E.M. Electronic Products

- *13 Year Product Development History*
- *Custom, RF/Digital ASICs* • *RF Systems*
- *Computerized Instrumentation*
- *Spread Spectrum Communications*
- *Finest Electronic Assemblies, Any Scale*

LocUS, Incorporated
1842 Hoffman St., Madison, WI 53704
608/244-0500 FAX 608/244-0528

CONTROL SYSTEM CONSULTING

- Servo design, high performance motion control, synthesis, system performance, simulation, specs, integration, testing
- Electrical, mechanical, hydraulic
- Defense, aerospace, industrial experience

30 East Gate Road A.R. Hazelton
Danbury, Conn. 06811 (203) 743-7002

T-TECH™

1 DEAN ST./BOX 151
HUDSON, MASS.
VOICE: (508) 562 5820 FAX: (508) [redacted] 1219

RF (TO 2 GHz), ANALOG, VIDEO, FIBER OPTICS, PLL'S, SYNTHESIZERS, FILTERS, A/D CONVERSION

THE MOST TIMELY, COST EFFECTIVE, AND HIGHEST PERFORMANCE SOLUTION.

EW System Consulting

- Hardware & Software Design, Analysis and Simulation • System Performance Requirements
- Specifications • Test Plans & Procedures
- System Integration & Testing

For further information contact:
Eckhard J. Schulz, Ph.D., President
ESEA, Inc **5150 El Camino Real # B-15**
(415) 962-1167 **Los Altos, CA 94022**

IRA J. PITEL, Ph.D.

Consulting, Research and Development in Power Electronics and Magnetics
Power Supplies, Inverters, Converters, Motor Drives, Lighting Controls, Industrial Controls, Transformers, and Special Magnetics.
MAGNA-POWER ELECTRONICS, INC.
135 Route 10 Whippany, NJ 07981
(201) 428-1197

Patent Attorney

Robert E. Malm, Ph.D. (M.I.T.)
Attorney At Law
Post Office Box 522
Pacific Palisades, CA 90272
Tel: (310) 459-8728
Fax: (310) 573-1781

Princeton Electro-Technology, Inc.

PERMANENT MAGNETS

MATERIALS, DEVICES & APPLICATIONS
CONSULTING, DESIGN, PROTOTYPES, MARKETING

Peter Campbell, Ph.D., President
2449 Patricia Avenue **Tel: (310) 287-0375**
Los Angeles, CA 90064 **Fax: (310) 287-0378**

NOISE, TRANSIENTS AND INTERFERENCE

- FCC, VDE, EMC/EMI
- Susceptibility, ESD, RF, Transients, Lightning
- Testing & Retrofit for Product Enhancement
- Speed to Market via Design Review
- Noise-Immune Designs and Prototypes
- FCC Compliance Training & Retrofits

TKC• THE KEENAN CORPORATION
(813) 544-2594
R. Kenneth Keenan, Ph.D.
Vice President, Engr.
8609 66th St. North
Pinellas Park, FL [redacted]

SOFTWARE ENGINEERING

- Real-Time Systems Analysis and Design
- Software Engineering Training (Call for Offerings)
- CASE Training and Implementation
- Consulting Services
- Product Development

Carl A. Argila, Ph.D., Inc.
SOFTWARE ENGINEERING CONSULTANT
800-347-6903

INDUSTRIAL CONTROLS

CUSTOM MICROPROCESSOR CONTROLS
- Machine Tool Controls
- Process Controls
- Medical Electronics
- Neural Networks
- Consumer Product Design
- Instrument Design
- Prototype Production
- Control Software

Wintriss Engineering Corporation
4715 Viewridge, San Diego 92123
(800) 733-8089 Vic Wintriss, MSEE

Infolytica Corp. (514) 849-8752

*Expert electromagnetics design & analysis using **MagNet 2D** and **3D** FEA software.*
- *motors*
- *transformers*
- *actuators*
- *levitators*
- *CRT design*
- *magnetizing fixtures*
- *recording heads*
- *NMR applications*
- *magnetic bearings*
- *etc. . .*

1140 deMaisonneuve, Suite 1160 Montreal, Canada, H3A 1M8

ELECTROMAGNETIC DESIGN ANALYSIS

Consultancy by world leaders in 3D electromagnetic computation using PE2D, OPERA, TOSCA and ELEKTRA
- electrical machines
- recording heads
- actuators
- transformers
- loudspeakers
- MRI scanners
- magnetic casting
- scientific apparatus
- NDT equipment
- accelerator magnets

VECTOR FIELDS INC. tel: (708) 851-1734
1700 N Farnsworth Ave, Aurora IL 60505 fax: (708) 851-2106

EM Research Engineering

Matt Eiting Pete Mastin, P.E.

RF/Microwave Circuit Design
- Amplifiers, Filters, Oscillators
- Receivers, Transmitters
- Synthesizers/PLL Design

2705 Highway 40 Suite 303A P.O. Box 1247 Verdi, NV 89439
(702) 345-2411

CONSULTING SERVICES

Editorial Offices: New York City 212-705-7555 San Francisco 415-282-3608 Washington, DC 202-544-3790

EDITORIAL CORRESPONDENCE. IEEE Spectrum, 345 East 47th St., New York, N.Y. 10017, Attn: Editorial Dept. Responsibility for the substance of articles published rests upon the authors, not the IEEE or its members. Letters to the editor may be excerpted for publication.
REPRINT PERMISSION. Libraries: Articles may be photocopied for private use of patrons. A per-copy fee (indicated after the code appearing at the bottom of the first page of each article) must be paid to the Copyright Clearance Center, 29 Congress St., Salem, Mass. 01970. *Instructors:* Isolated articles may be photocopied for noncommercial classroom use without fee. *Other copying or republication:* Contact: Editor, *IEEE Spectrum*.
ADVERTISING CORRESPONDENCE. IEEE Spectrum, 345 East 47th St., New York, N.Y. 10017, Attn: Advertising Dept. 212-705-7760. Also see Advertising Sales Offices listing on last page. The publisher reserves the right to reject any advertising.
COPYRIGHTS AND TRADEMARKS. IEEE Spectrum is a registered trademark owned by The Institute of Electrical and Electronics Engineers, Inc. EEs' Tools & toys, Faults & failures, Innovations, Legal aspects, Managing technology, Newslog, Program notes, Reflections, Speakout, Spectral lines, Spinoffs, Technically speaking, The engineer at large, and Whatever happened to? are trademarks of the IEEE.
GENERAL INQUIRIES: 1-800-678-IEEE; Headquarters: 345 East 47th St., New York, N.Y. 10017, 212-705-7900. *Tel. extensions at headquarters:* General Manager, 7910; Public Relations, 7369; Publishing Services, 7560. *At other locations:* Regional Activities, Section Services, Educational Activities, 908-981-0060 or write to IEEE Service Center, Box 1331, Piscataway, N.J. 08855; Membership Services, 908-981-0060; Professional Services, 202-785-0017; Technical Activities, 908-562-3900.

Scanning
The Institute

Teach-in counts on many engineers

About 20 000 engineers—twice as many as last year—were scheduled to participate in teach-ins in schools across the country to promote engineering among elementary, middle, and high school students during National Engineers Week, Feb. 16–22. The engineers, including about 1000 IEEE members, were to talk to students and show them videotapes about the engineering profession in the hopes of interesting them in careers in engineering. This year's teach-in, called Discover "E" (for engineering), was the third annual and the first to emphasize reaching out to minority students [THE INSTITUTE, March/April, p. 1].

Hot line for engineers

A program aimed at making U.S. students preeminent in math and science achievement has attracted more than 1700 engineers in its few months of operation. The Engineers for Education (E for E) program hopes to recruit more than 100 000 volunteers—30 000 of them being IEEE members—by the year 2000, one for almost every school in the United States. E for E was formed last year by a coalition of 45 engineering societies under the auspices of the American Association of Engineering Societies, Washington, D.C.

The volunteers will try to persuade students to pursue careers in engineering by conducting classroom demonstrations, organizing career days, and guiding field trips, among other activities. For information, would-be volunteers may dial E for E's number, 800-489-0348 [THE INSTITUTE, March/April, p. 1].

Sponsors sought for skills assessment

ESAP, the Engineering Skills Assessment Program, is being developed by IEEE volunteers to supply the tools for assessing how well IEEE members know their own and other electrical engineering disciplines. Now, corporate sponsors are being sought to contribute US $10 000 each to help speed the development and introduction of the ESAP packages. In return, each sponsor will have an ESAP package developed in the field of its choice, and will also receive advance copies of every other package that's developed.

ESAP has made good headway in the past few months, with a half-dozen ESAP packages developed in various engineering subjects and over a dozen more in the works. In addition to providing the skills assessment, the ESAP packages describe the duties and knowledge deemed important in each field, and provide guidance for self-study and matriculation [THE INSTITUTE, March/April, p. 8].

Pioneers who left a lasting mark

Rear Admiral Grace Murray Hopper (U.S. Naval Reserve, Retired) died on New Year's Day in her home in Arlington, Va., at the age of 85. She is best known for the development of computer programming languages that simplified the human interface with computer technology. She was awarded the National Medal of Technology by President Bush in 1991.

Sven H. Dodington (LF), inventor of one of the first basic navigation systems used to guide aircraft, died on Jan. 13 at age 79. He developed the system, which is also used for air traffic control, that directs planes to airports using radio beacons and distance-measuring equipment. Dodington's awards included the IEEE's Pioneer Award [THE INSTITUTE, March/April, p. 11].

Coming
in Spectrum

Iraq and the bomb. How close did Iraq come to creating nuclear weaponry—and how was it able to come so close? This three-part report looks at the history of the country's nuclear program and weighs possible future methods of monitoring the nuclear efforts of other nations more closely.

Master of entropy. Claude Shannon was the first to apply Boolean algebra to the functioning of switches in electric circuitry and later fathered information theory—two foundation stones of modern computing and communications.

Update on workstations. This five-part report on what has happened over the last 12 months in the workstation arena opens with a survey of what users think. Half a dozen tables will list the brands they favor, for what purposes, and in which areas. The design disciplines that benefit will be tabulated, as will be preferences in application and system software.

The other four parts will cover:

• Commercially available workstations, with new important features highlighted.

• Add-ons, such as hardware accelerators, adapter boards, storage systems, input devices, and output systems.

• The impact on workstation design of commercially available ICs.

• Network management software.

Suggestions for further reading, a page of definitions, and an index will complete the package.

ADVERTISING SALES OFFICES

345 East 47th Street, New York, N.Y. 10017

William R. Saunders	Advertising Director	705-7767
Michael Triunfo	Northeastern Manager	705-7312
Hendrik Prins	Research Manager	705-7067
Theresa Fitzpatrick	Advertising Production Manager	705-7579

Boston, Mass.–Gerard S. Mullin, Doug Long, The Channel, Brewster, 02631 508-896-5930

Philadelphia, Pa.–Daniel P. Mainieri Jr., Regional Manager, 650 N. Cannon Ave. #22, Lansdale, 19446 215-368-8232

Chicago, Ill.–Ralph Bergen, One Northfield Plaza, Suite 300, Northfield, 60093 708-446-1444

San Francisco, Calif.–Denis F. Duffy, 3755 Balboa Street, Suite 201, 94121 415-386-5202

Los Angeles, Calif.–Lynne Andrew Evans, 5777 West Century Boulevard, #635, 90045 310-649-3800

Atlanta, Ga.–H. Michael Coleman, C. William Bentz III 4651 Roswell Road N.E., 30342 404-256-3800

Dallas, Texas–Matt Kincaid, 9794 Forest Lane, Suite 634, 75243 214-553-9896

Tokyo, Japan–German Tajiri IMI Corp., Saito Lend Bldg., 13-5, Ginza 3-chome, Chuo-ku, Tokyo 104. (03) 3546-2231. TELEX: J23449 (IMI TOKYO)

Munich, Germany–Ric Bessford, Leopoldstr. 52, 8000 Munich 40, Germany, 49-89-39-00-55

Publisher: Donald Christiansen
Administrative Assistant: Nancy T. Hantman
Associate Publisher: William R. Saunders (Advertising)
Administrative Assistant: Carmen Cruz
Vice President, Publications: James T. Cain

ADVERTISERS INDEX

Circle numbers on the Reader Service Card, opposite page 54, that correspond to the advertisers listed below. * Advertiser in North American edition.

RS#	Advertiser	Page #
20	Ansoft	60
16	Bimillennium	2
	CACI	1
50	*Cermetek Microelectronics	52A
25	*CLEO	12K
11	Computer Associates	32–33
6	CSPI	8
29	*Design Science	12H
3	Dialog	22
1	DSP Development	cover 4
5	Gigatec	17
38	*Inspec	12 I
33	*Integrated Engineering Software	12 I
	*IEEE Educational Activities	12J
39	IEEE Membership Development	12J
21	IEEE Press	58
8	Intusoft	11
10	Jandel Scientific	59
40	*John Wiley & Sons	12C
15	MacNeal Schwendler	12
2	Mathsoft	13
7	Mathworks	cover 2
41	Maxwell Labs	19
31	Mitchell & Gauthier	20
14	Momentum Data Systems	cover 3
4	Motorola Computer Group	21
37	*Motorola DSP	12 I
17	National Instruments	18
51	*National Instruments	52A
	NEC	14–15
19	Polyhedron Software	52
32	Precision Visuals	7
	Queensland University of Technology	53
36	*Quinn Curtis	12D
13	Scientific Endeavors	52
35	Scientific Programming	11
	*Seabury & Smith	12G
53	*Severn Communications	52A
34	*Soft Warehouse	12B
30	*3D Visions	12A
18	University of Pennsylvania	53
52	*Walker Scientific	52A

MOMENTUM UNLOCKS INTEGRATED DSP SOLUTIONS

GET YOUR KEY FOR UNLOCKING POWERFUL EASY-TO-USE DSP SYSTEMS

Presenting the premier products from Momentum Data Systems

QEDesign™ gives you the key to designing the most basic to the most complex digital filters that you'll ever need.

DSPworks™ helps you unlock DSP solutions with its real-time data acquisition and signal processing.

Momentum Code Generators lock up your winning edge. Designed to create highly optimized assembly language programs with QEDesign.

Momentum products save you time and money with their menu-driven and easy-to-use solutions. No long learning curve or complex commands to memorize.

Momentum is dedicated to serving its customers by unlocking integrated DSP solutions. Whether its software only, or a combination of both hardware and software, Momentum has the key.

Momentum has software and hardware products available on SUN SPARCstations, Macintosh, PC's and Windows 3.0, and offers complete sales, service, training and consulting services.

Use the Momentum Key to unlock the best DSP solutions available from one company. Call today for a complete demo kit.

714-557-6884

MOMENTUM
DATA SYSTEMS INC.

1520 Nutmeg Place, Suite 108, Costa Mesa, CA 92626, U.S.A.
Ph (714) 557-6884 Fax (714) 557-6969

Australia: SPA (Pty) Ltd. Tel: (3) 729-0995, Fax (3) 720-4298; **Denmark:** Assentoft Electronics, Tel 86 16 29 26, Fax 86 16 20 12; **France:** Excem, Tel (1) 47 52 13 44, Fax (1) 47 77 03 43; **Germany:** Electronic Tools, Tel (2102) 88010, Fax (2102) 880123; **India:** Signion Systems, Tel (842) 38085; **Italy:** CAD Italia Srl, Tel (2) 617 2521, Fax (2) 612 0003 **Switzerland:** IDK, Tel (56) 27 27 77, Fax (56) 27 27 59; **United Kingdom:** SSE Marketing, Tel (71) 387-1262, Fax (71) 387-1262, Fax (71) 388-0339.

Product names are trademarked to their respective companies.

Circle No. 14

See us at ICASSP Booth 316-415